NASA CR-112,228

USER'S MANUAL

BUCLASP 3

A COMPUTER PROGRAM FOR STRESSES AND BUCKLING OF HEATED COMPOSITE STIFFENED PANELS AND OTHER STRUCTURES

by

L. L. Tripp, M. Tamekuni, and A. V. Viswanathan

MARCH 1973

(NASA-CR-112228) BUCLASP 3: A COMPUTER PROGRAM FOR STRESSES AND BUCKLING OF HEATED COMPOSITE STIFFENED PANELS AND OTHER (Boeing Commercial Airplane Co., Seattle) ~~221~~ 231 p HC CSCL 20K G3/32 N73-24895 Unclas 03852

Prepared under Contract NAS 1-8858

by

BOEING COMMERCIAL AIRPLANE COMPANY
Seattle Washington

for

LANGLEY RESEARCH CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

231

N73-24895

NASA CR-112,228

USER'S MANUAL

BUCLASP 3

A COMPUTER PROGRAM FOR STRESSES AND BUCKLING OF HEATED COMPOSITE STIFFENED PANELS AND OTHER STRUCTURES

by

L. L. Tripp, M. Tamekuni, and A. V. Viswanathan

MARCH 1973

Prepared under Contract NAS 1-8858

by

BOEING COMMERCIAL AIRPLANE COMPANY
Seattle Washington

for

LANGLEY RESEARCH CENTER

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

230

FOREWORD

This work was sponsored by the National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia under Contract No. NAS1-8858, Phase III.

The work was performed under the direction of program manager Dr. Ralph E. Miller, Jr. of The Boeing Company and technical monitor Dr. Michael F. Card of NASA.

ABSTRACT

This manual describes the use of the computer program BUCLASP3. The code is intended for thermal stress and instability analyses of structures such as unidirectionally stiffened panels. There are two types of instability analyses that can be effected by PAINT; (1) thermal buckling and (2) buckling due to a specified inplane biaxial loading. Any structure that has a constant cross section in one direction, that may be idealized as an assemblage of beam elements and laminated flat and curved plate strip-elements can be analyzed. The two parallel ends of the panel must be simply supported, whereas arbitrary elastic boundary conditions may be imposed along any one or both external longitudinal side.

Any variation in the temperature rise (from ambient) through the cross section of a panel is considered in the analyses but it must be assumed that in the longitudinal direction the temperature field is constant. Load distributions for the externally applied inplane biaxial loads are similar in nature to the permissible temperature field.

This manual consists of instructions for the use of the program with sample problems, including input and output information. The theoretical basis of BUCLASP3 and correlations of calculated results with known solutions, are presented in Ref. 1.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

1.0 SCOPE OF BUCLASP3

The computer program BUCLASP3 is designed to perform the following types of analyses for unidirectionally-stiffened, rectangular composite panels.

(1) Thermal stress
(2) Thermal buckling
(3) Buckling due to a mechanical biaxial inplane load distribution varying through the panel cross section.

The structure must be idealized as an assemblage of beam elements and laminated curved and/or flat plate strip elements. Each element extends the full length of the structure. The element edges which are normal to the longitudinal axis of the panel are assumed to be simply supported and any external edge parallel to the longitudinal axis may be arbitrarily constrained by specifying appropriate spring constants. When needed, plate offsets can be utilized to correctly idealize a structure.

The stress and buckling analyses are based on the linear elastic theory. In the buckling formulation, prebuckling deformations and initial imperfections are not considered. Applied loads may be comprised of axial and transverse plate inplane loads, N_{11} and N_{22}, and axial beam loads. These inplane applied loads are input as internal loads and are assumed to be constant in the longitudinal direction.

As discussed in Ref. 1, the selection of sinusoidal variations of displacements in the longitudinal direction makes it possible, for purposes of analysis, to treat the structural elements as if they were in the cross section of the structure. Thus, each two- dimensional plate element is completely defined as a one-dimensional member and each beam element is defined as a point in the panel structure cross section.

By prescribing a set of wave numbers, one obtains a separate buckling solution for each corresponding half wave length. For each solution, the mode shape in the longitudinal direction is sinusoidal and has the number of specified half waves. After the solutions for each of the input wave numbers are calculated, the minimum buckling load is automatically selected and if specified, the mode shape through the cross section of the structure is computed for the critical wave number.

In the buckling analyses of (2) and (3) above, the plate elements must be subdivided along the width into a specified number of sub-elements (see Figure 2.3.1). The division is made such that the subelements have equal widths and span the total length of the panel. The applied loads are assumed to be constant in each subelement, but may vary from one subelement to another. The beam axial loads are also assumed to be constant. Shears and moments for all element types are ignored in the analysis.

The thermal stress and thermal instability analyses account for temperature variations through the panel cross section. It is assumed, however, that the temperature is constant in the longitudinal direction. The load distributions for (3) above are similar in nature to the permissible temperature field.

1.1 Thermal Stress Analysis

Temperature variations within a panel that may be analyzed by the thermal stress analysis program were discussed previously. In each case, the temperature distribution (a constant value) is expanded as a truncated Fourier sine series. By choosing appropriate Fourier series expansions as functions of the longitudinal direction for all displacements and stresses, the thermal stresses are computed for each odd numbered harmonic (wave). The final stresses and displacements are determined by summing the contributions from each harmonic. These stresses and displacements are printed with respect to element local axes. The adopted stress and displacement sign conventions for plate elements and beam elements are illustrated in Figure 2.2 and 2.4.1, respectively.

1.2 Thermal Instability Analyses

Two types of thermal instability analyses can be performed by BUCLASP3.

(1) Buckling caused by thermal effects only (thermal buckling). The critical temperature ratio, defined as the factor by which the specified temperature distribution is multiplied where buckling occurs, is computed.

(2) Buckling due to mechanical axial loads, N_{11} (mech.), on a panel exposed to a specified invariant temperature distribution.

In both cases, a thermal stress analysis is performed first. In general, the computed thermal plate stresses, N_{11} (therm.) and N_{22} (therm.) are characterized by a two-dimensional variation within each subdivided plate element. These stresses are calculated at the subelement mid-widths and are averaged in the longitudinal direction. These average stresses are then applied to each subelement as constant prestress loads. All other thermal stress components are ignored in the buckling analysis. The prestress loads, constant within any subelement, but varying from one subelement to another, account for the possible varying nature of the plate thermal stresses in the transverse direction. Beam element axial loads are averaged and are applied as constant prestress loads for the buckling analysis.

In (1) above, the factor that all plate subelement and beam prestress loads are multiplied by, which causes buckling, is computed. This factor, greater than 1.0, is called the critical temperature ratio. At buckling, the panel prestress load distribution is identical, with the exception of magnitude, to the initially computer prestress load distribution.

For (2) above, a mechanical axial load, N_{11} (mech.) is superimposed on the prestress loads (from thermal stresses). The N_{11} (mech.) axial load is distributed to all elements such that longitudinal strain compatibility is satisfied. This compatibility condition is satisfied with the N_{11} (mech.) load only, excluding the prestress loads. The critical N_{11} (mech.) load that causes panel buckling is computed for this option. The thermal prestress loads remain invariant throughout the buckling computations.

For both options above, the user must ensure that the input temperature distribution is not too large that it hasn't already caused the panel to buckle. This is necessitated by the restrictions imposed on; (1) above, where only critical temperature ratios greater than one are considered, and (2) above, where tensile N_{11} (mech.) loads are excluded from the calculations.

1.3 Instability Analyses of Panels Subjected to Mechanical Loads

There are two options for buckling analysis of panels subjected to mechanical, biaxial inplane loads. They are:

(1) Critical load ratio option, where the critical load ratio is defined as the magnitude of the buckling load distribution divided by the magnitude of the initially specified inplane load distribution.

(2) Buckling option due to an initially specified load distribution upon which an additional applied axial load, $\bar{N}_{11}$ is superimposed. The critical value of $\bar{N}_{11}$ is computed for a panel that is initially prestressed by input loads. The prestress loads are assumed to remain constant throughout the buckling computations.

These two options are treated in an identical manner as the options previously discussed for thermal instability analyses. Replacing the computed thermal prestress loads by the input plate subelement loads, N_{11} (input) and N_{22} (input), and the input beam axial loads, the buckling analyses are performed in the same manner as the thermal instability analyses.

Again, only uniform N_{11} and N_{22} inplane loads for plate subelements and constant axial loads for beams are considered. The same restrictions defined for the thermal instability options are also applicable here.

2.0 BASIC INFORMATION

This section presents basic information required by BUCLASP3 users for performing stress and buckling analyses. Figure 2.1 shows the cross section of a structure. The circled numbers are element numbers. Extremities of each plate element and the shear centers of each beam element are indicated by dots. The dashed line is drawn through the mid-planes of each plate element.

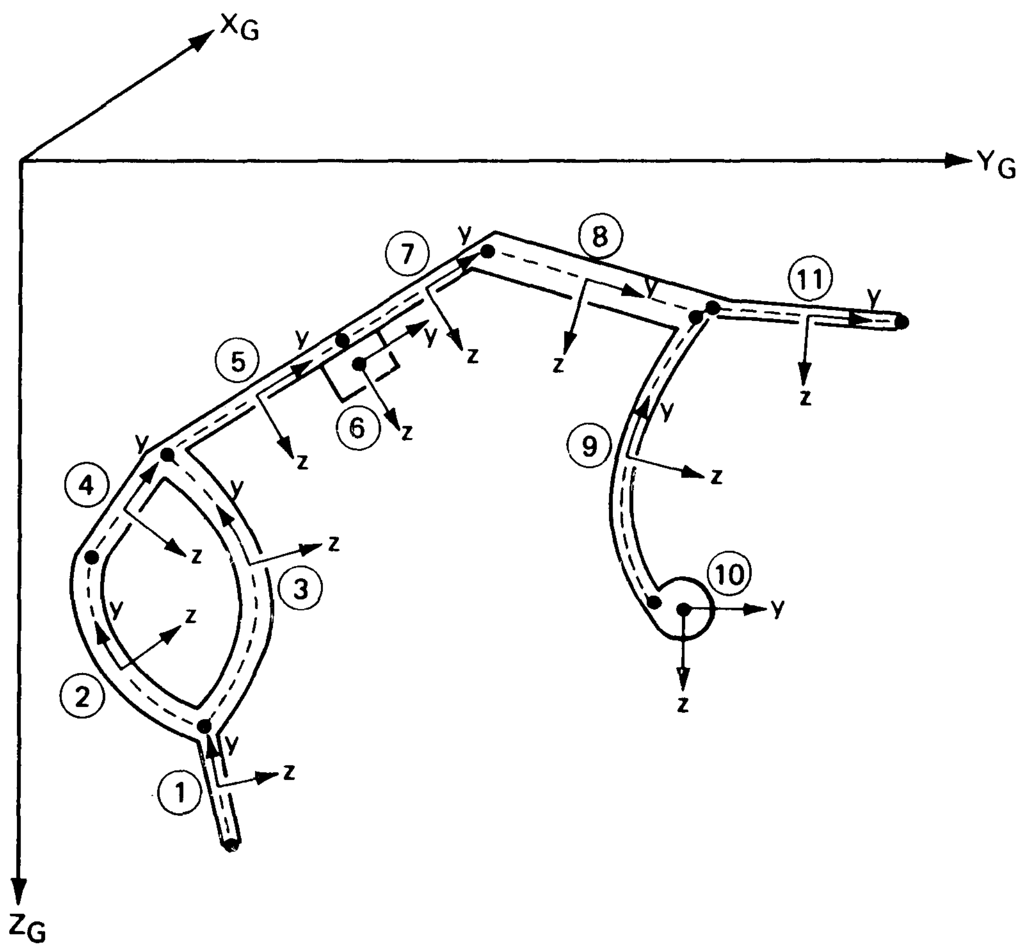


Figure 2.1 Idealization of an Arbitrary Structure

2.1 Geometry

2.1.1 Coordinate Systems

All structural geometries are defined relative a global (overall) right-handed rectangular Cartesian coordinate system. The axes of this triad are denoted by X_G, Y_G and Z_G in Figure 2.1. The longitudinal axis of the panel is in the same direction as X_G. Local element coordinate systems will be discussed individually for each element in Section 2.2.

2.1.2 Nodes

The dots shown in the Figure 2.1 will be referred to as nodes. <u>They are actually lines that are parallel to X_G</u>. A node is identified by its coordinates in the global system and by its user-assigned node number. This node number is only for the user's convenience since the program automatically numbers the nodes sequentially according to the input order. The first input node will be internal node number 1, the second input node, 2, etc. Generally, the user-assigned node numbers will not be the same as the internal node number. No reordering of nodes is done internally.

2.2 Elements

There are three basic types of elements: (1) flat plate, (2) curved plate, and (3) beam elements. All elements extend the full length of the structure. A plate element is defined by a pair of node numbers that correspond to the sides of the element. In Figure 2.2 the plate element is defined by nodes A and B. A beam element is defined by a node that corresponds to the beam shear center. In Figure 2.1 the following observations can be made:

(a) ① , ④ , ⑤ , ⑦ , ⑧ , and ⑪ are flat plate elements.

(b) ② , ③ , and ⑨ are curved plate elements.

(c) ⑥ and ⑩ are beam elements.

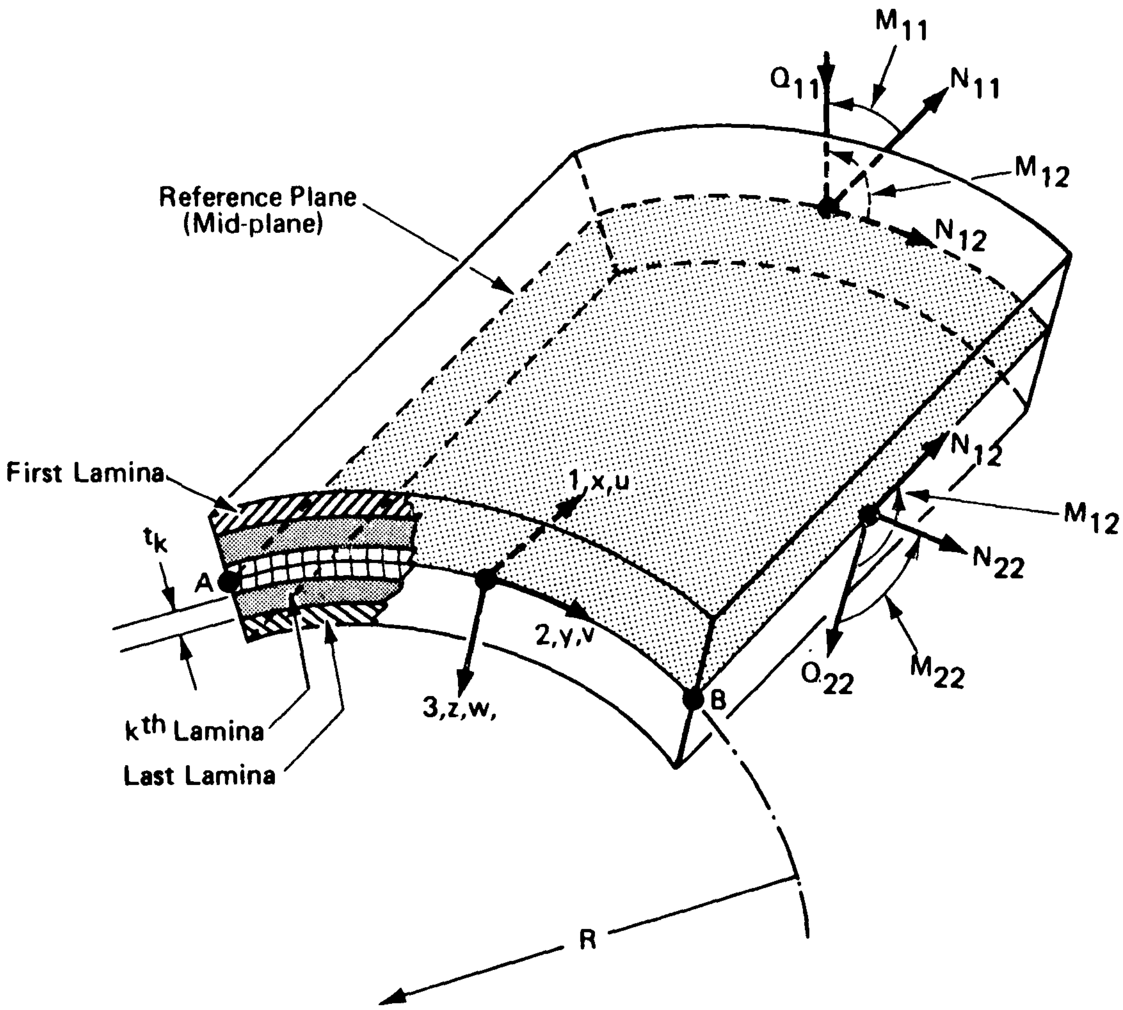


Figure 2.2 Laminated Plate Element

2.2.1 Plate Elements

There are two types of plate elements, flat and curved. The following discussion applies to both types except when reference is made to a particular type of plate element:

Local Coordinate System

The local coordinate system of a plate element is defined by the ordering of the node numbers that identify the element. The local y axis of the plate element is in the direction from the first node of the element to its second node. For example, in Figure 2.2 the element is defined from node A to node B, and the resulting direction of the local y axis of the element is as shown. The local y axis of the curved plate element is along the arc from A to B. The local x axis is parallel to and in the same direction as X_G. The local z axis is determined by the right-hand rule. The origin of the local axes is on the mid-surface of the element and midway between its nodes.

Properties

In its most general form, the plate element can be multi-layered, each layer being orthotropic with respect to the local plate axes. In its simplest form, the element degenerates to a single isotropic layer. The thickness of each layer is assumed to be constant. The user must specify the thickness and material property of each layer.

The first lamina of a laminated plate element is defined as the external layer in the negative z direction. The last lamina is the extreme layer in the positive z direction (see Figure 2.2). It is important that the layers are input in this particular order.

Radius of Curvature of Curved Plate

The curved plate element is actually a strip of a circular cylindrical shell. Therefore, only one radius of curvature, R, need be defined for this element. The sign convention for R is defined in the following manner: R is positive if the vector from the element to the center of curvature is in the same direction as the local z axis of the element. The magnitude of R is measured from the mid-surface of the element to the center of curvature. In Figure 2.3 the sign of R for elements (a) and (b) is negative, whereas it is positive for element (c).

Temperature Distribution

The temperature field within a plate element is expressed as:

$$T_p = T_{px} \cdot T_{py} \cdot T_{pz}$$

where T_p = plate temperature,

T_{px} = variation of the temperature field in the x direction,

T_{py} = variation of the temperature field in the local y direction,

and T_{pz} = variation of the temperature field in the local z direction.

T_{px} is assumed to be a constant as discussed previously. T_{py} may be specified either as a constant or as a variable by inputting the coefficients, a_y, b_y and c_y, in the following polynomial,

$$T_{py} = a_y y^2 + b_y y + c_y,$$

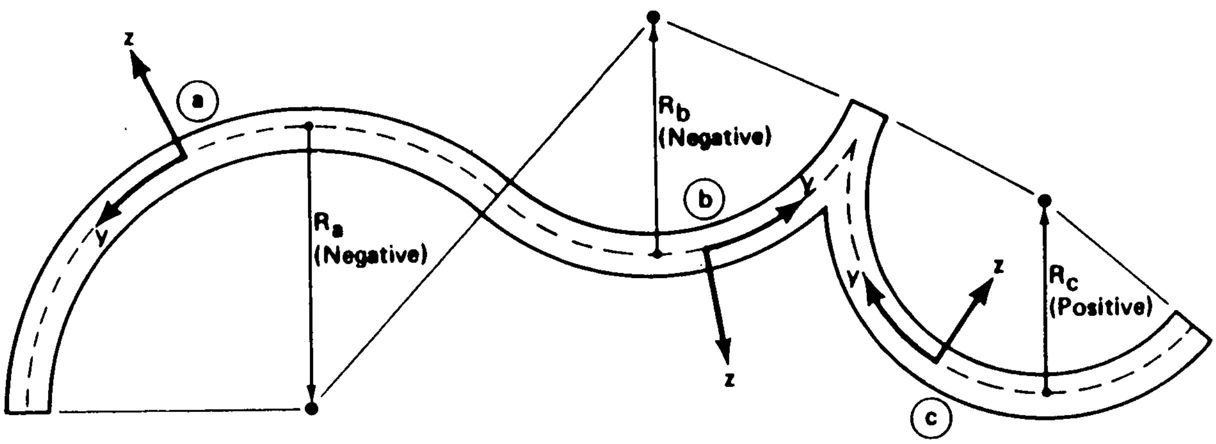


Figure 2.3 Curved Plate Elements

where y is the local axis of the element in the plate width direction. T_{pz}., which is treated in the analysis as a constant for each layer of the plate element, may be specified in two different manners; (1) a constant value for each layer or (2) a variable expressed by the coefficients A_z, B_z and C_z in the following polynomial,

$$T_{pz} = A_z + B_z\bar{z} + C_z\bar{z}^2,$$

In this relation, $\bar{z}$ is the distance measured along the local z axis of the plate element from the element outer surface. When a user defines T_{pz} as a function of $\bar{z}$, the program computes T_{pz} at the mid-surface of each layer and applies this value to the layer as a constant.

If the thermal field varies in the local z direction within a layer, the layer may be idealized in the following manner. Assume this lamina to be multi-layered and input constant values for T_{pz} to approximate the actual variation through the thickness.

Applied Loads

When the option to compute buckling loads for a panel subjected to only mechanical loads is used, the initial inplane biaxial loads must be specified. They are specified as constant values for each subelement. Tensile loads are input as positive values and compression loads as negative values.

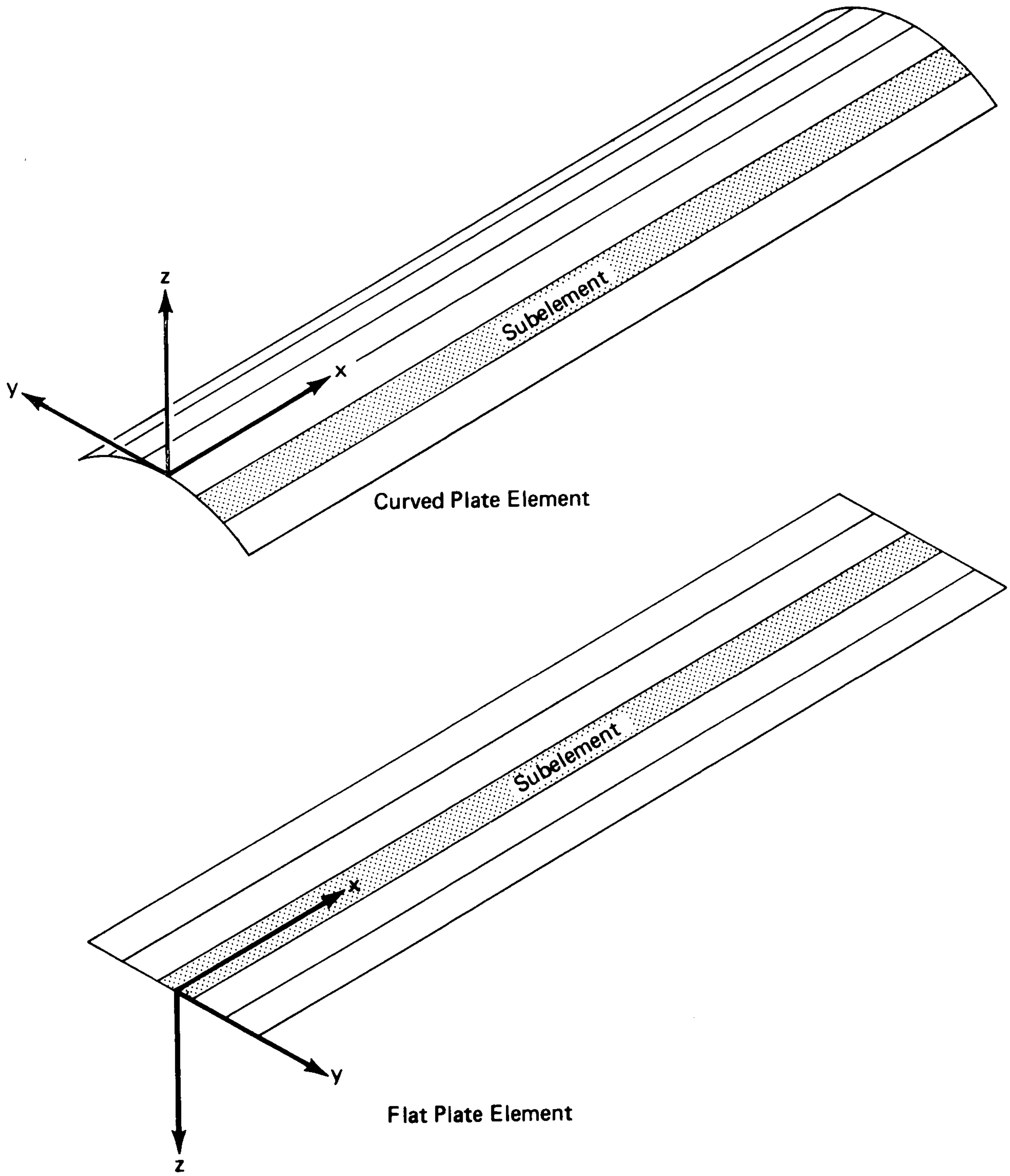


Figure 2.3.1 Subdivided Plate Elements

2.2.2 Beam Elements

There are two basic types of beam elements that are available in BUCLASP3. They are the laminated beam element, rectangular or circular in cross section, and the general beam element. The local x axes of all beam elements are directed in the same direction as the local X_G axis and parallel to it.

Laminated Beams

Rectangular:

The rectangular laminated beam is shown in Figure 2.4(a). The depth of each layer is b. The origin of the local axis system is at the shear center, 0, of the beam. The local y axis of this element could either be in the direction as shown in Figure 2.4(a) or in the opposite direction. The local z axis is determined by using the right hand rule.

The laminae are ordered sequentially in the direction of the local y axis as indicated by Figure 2.4(a). Thus, if the local y axis were in the opposite direction, the ordering of the layers would be reversed.

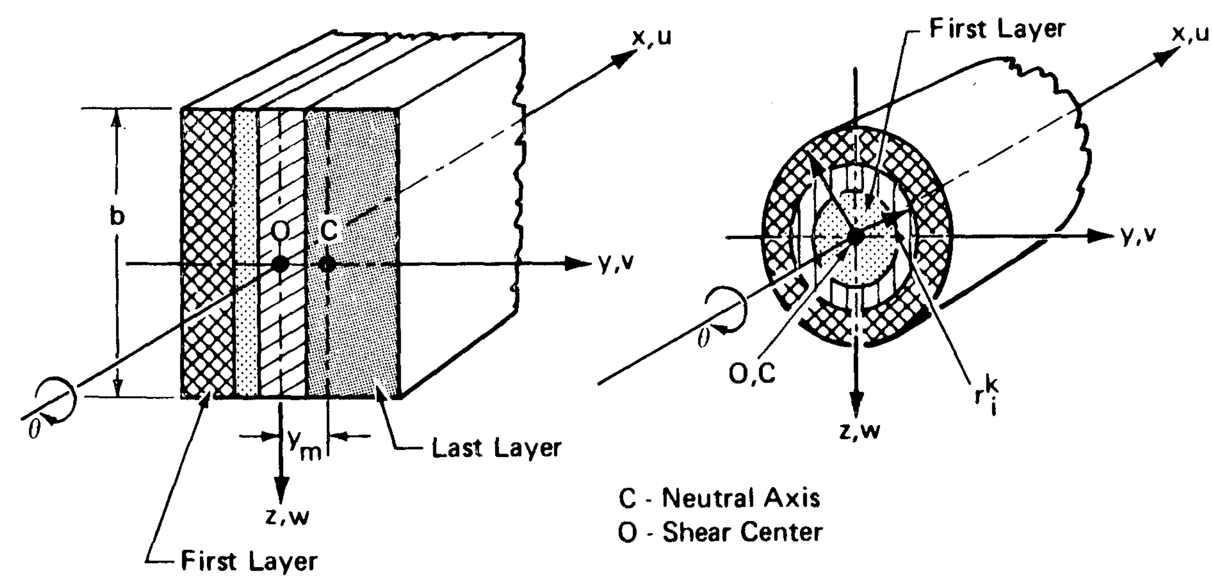
The temperature distribution within each beam layer is expressed as:

$$T_b = T_{bx} \cdot T_{by} \cdot T_{bz}$$

where T_b = beam temperature,

T_{bx} = temperature variation in the axial direction,

T_{by} = temperature variation in the local y direction



(a) Laminated Rectangular Beam

(b) Laminated Circular Beam

Figure 2.4 Laminated Beam Elements

and T_{bz} = temperature variation in the local z direction.

T_{bx} and T_{by} are assumed to be constant and T_{bz} is specified either as a constant for each layer or by the following polynomial.

$$T_{bz} = a_z + b_z z + c_z z^2$$

where z is the local axis of the beam. The T_{bz} values are automatically calculated at the middle of each layer and these values are used in the analysis as constant values.

Circular:

The beam is laminated in the manner shown in Figure 2.4(b). The first layer is the innermost layer and the ordering of the layers extends outward. The local y axis of this element can be in any direction in the plane of the beam cross section. The local z axis is again determined by the right hand rule. The temperature distribution is specified as a constant for each lamina.

General Beam Element:

The local y axis of the element can be in any direction in the place of the beam cross section. The local z axis is defined by the right hand rule. Properties such as inertias, areas, torsion constants and warping constants are input with respect to the local coordinate system. The orientation of a beam element is defined relative to the global coordinate system by specifying the angle between the global and local axes.

For the thermal analyses, the thermal loads are input for this beam type. These thermal loads can be computed from equations (4.53) to (4.55) of Reference 1.

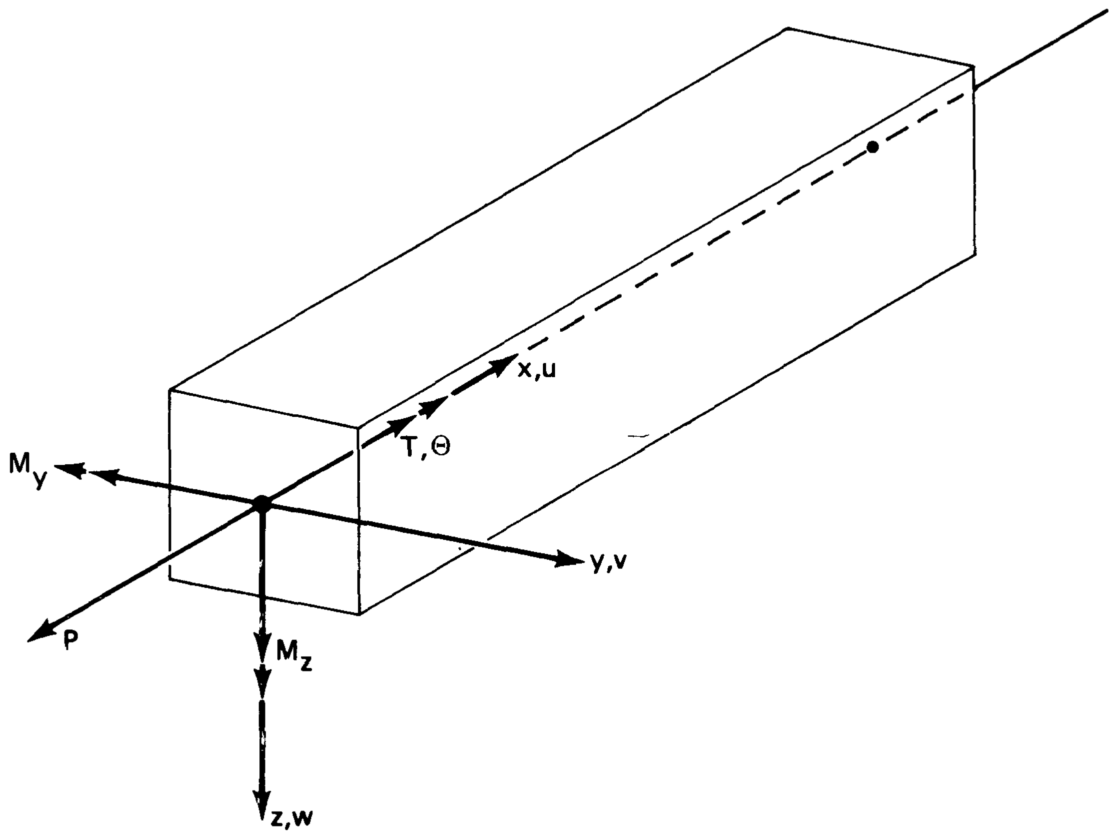


Figure 2.4.1 Beam Forces and Displacements

2.3 Offsets

The element stiffnesses are originally defined at the element "local nodes". A plate element has two "local nodes" defined as the longitudinal edges lying in the mid-surface and the "local node" for a beam element is defined by its shear center. When two or more elements are joined together, the appropriate element stiffnesses can be merged at the juncture if the "local nodes" of all elements are coincident at the juncture. If the "local nodes" at this juncture are not coincident, it is necessary to define a common node where all the element stiffnesses can be merged properly. By necessity this common node must be a user input node. By using plate offsets, the user effectively defines the element stiffness at some node other than the plate "local node", thereby, giving him a tool to meet the above requirements. This non-"local node" is referred to as an "offset node". It must, however, be one of the user-defined nodes.

A plate with offsets can be interpreted as a pseudo plate element with a "link" connecting one of the plate "local nodes" to an "offset node". This link allows the element stiffness at a "local node" to be transferred to an "offset node".

There is no offset capability for the beam element in this program. This, however, is not detrimental since in all cases plate offsets can be used to idealize non-coincident junctures.

A situation where plate offsets can be used is when the mid-surfaces of plates do not intersect at the juncture. Offsets can also be used when the shear center of a beam does not coincide with the mid-surface of an adjoining plate.

The plate offset is a vector which is specified by two components, y_0 and z_0 from the edge of the plate element (see Figures 2.5.1 and 2.5.2). The y_0 and z_0 vector components are measured relative to the local y and z axis respectively. They are positive when their directions coincide with the positive directions of the local axes. z_0 is measured from the negative-z plate surface (exterior surface in the negative-z direction) and y_0 is measured from the plate "local node". It must be emphasized that z_0 is not measured from the "local node".

Figure 2.5.1 illustrates the cross section of a panel in which two plate elements intersect a beam element. The input nodes coincide with the plate "local nodes" but they are not coincident with the beam shear center. Since these nodes are not coincident at the juncture and a beam offset capability is not available, offsets for plate elements 1 and 3 must be specified. Consequently, the element stiffnesses will be merged at 3, the beam node.

Figure 2.5.2 illustrates two examples where plate elements of unequal thicknesses meet. In the top figure, the mid-surfaces of plate elements 1 and 3 with equal thicknesses passes through the input nodes. Element 2 , however, is a two-layered plate with a different thickness. Since the stiffness for element 2 is formulated relative to its "local nodes", offsets must be defined to transfer this stiffness to nodes 2 and 3 to ensure the desired structural integrity. If offsets were not specified for this example, the true configuration of this structure would not be retained in the analysis. That is, element 2 would be situated such that its mid-surface coincides with the mid-surfaces of 1 and 3.

It should be noted that z_0 is not the offset distance from a plate "local node" to the "offset node". This offset component, however, is used by the program to formulate the actual offset-transfer of the stiffness. For example, the stiffness at the mid-surface of (2) in Figure 2.5.2, is transferred to nodes 2 and 3 based on the z_0 offset indicated therein.

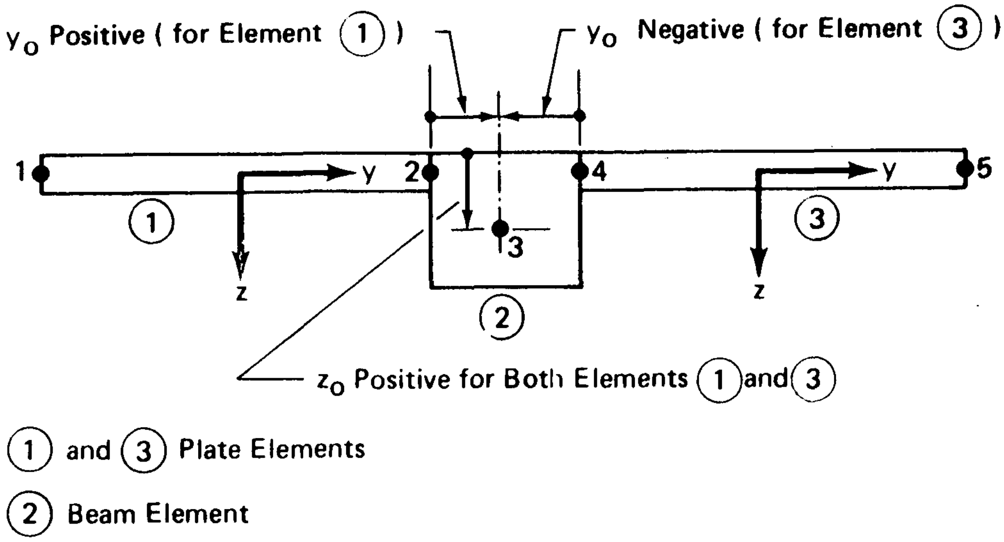


Figure 2.5.1 Offsets in Presence of Beams

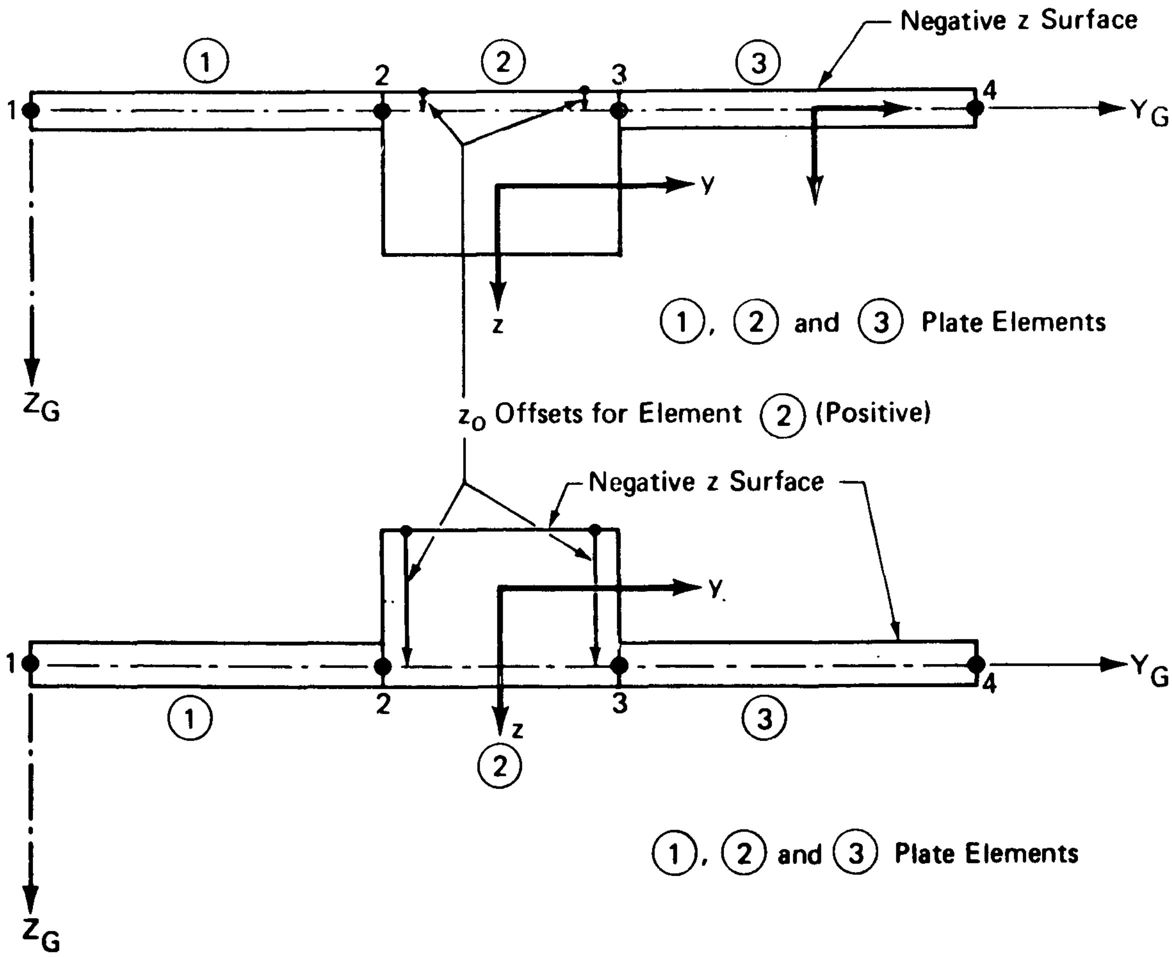


Figure 2.5.2 Plate Offsets

2.4 Boundary Conditions

An external side parallel to the X_G axis of a plate element may be constrained by specifying one of the following types boundary conditions:

(a) Simply supported

$$w = M_{22} = N_{22} = u = 0$$

(b) Clamped

$$w = \theta = N_{22} = u = 0$$

(c) Free

$$\theta = M_{22} = N_{22} = N_{12} = 0$$

(d) Sprung

The constrained or sprung degrees of freedoms are defined with respect to the local coordinate system of the plate element. Boundary conditions cannot be applied to a beam element node or an internal node. For a sprung node of a plate element, the spring stiffnesses for all four degrees of freedom must be specified. To delete or constrain a freedom, use a large value for the corresponding spring constant, e.g., 1×10^{100}.

2.5 Substructures

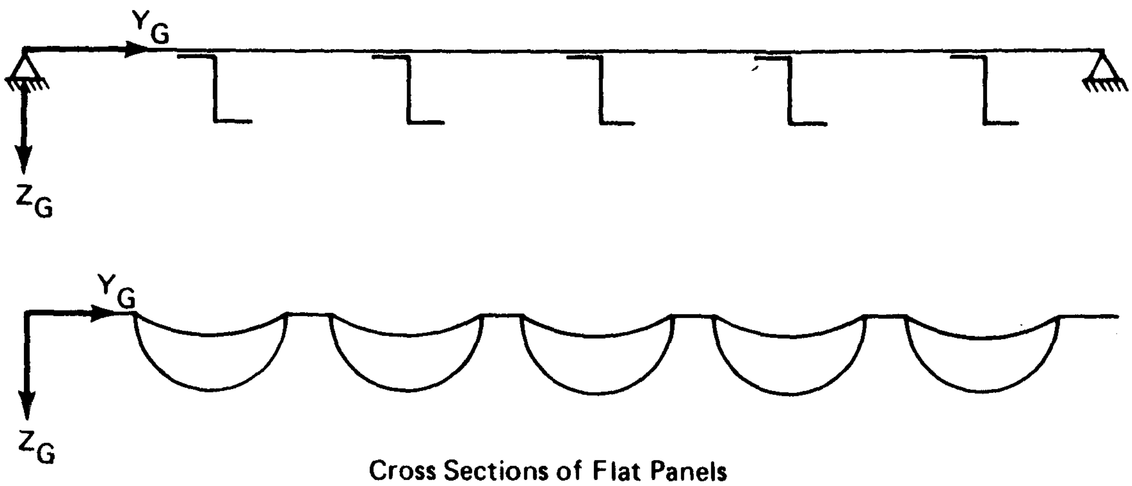
Three types of substructures are considered in PAINT; (1) start, (2) repeat and (3) end. The basic reason for including these substructures is to avoid repetitious computations that is generated by panels with many repeated structural groups. Also, higher efficiency can be achieved by dividing the stiffness matrix into separate blocks, each block corresponding to a substructure, during the buckling load computation. The user input is also reduced.

The user may divide a panel, with or without repetitive structural groups, such that is consists of one start substructure, one, many, or no repeat substructures and one end substructure. Further, a panel may be idealized with the following combinations of substructures;

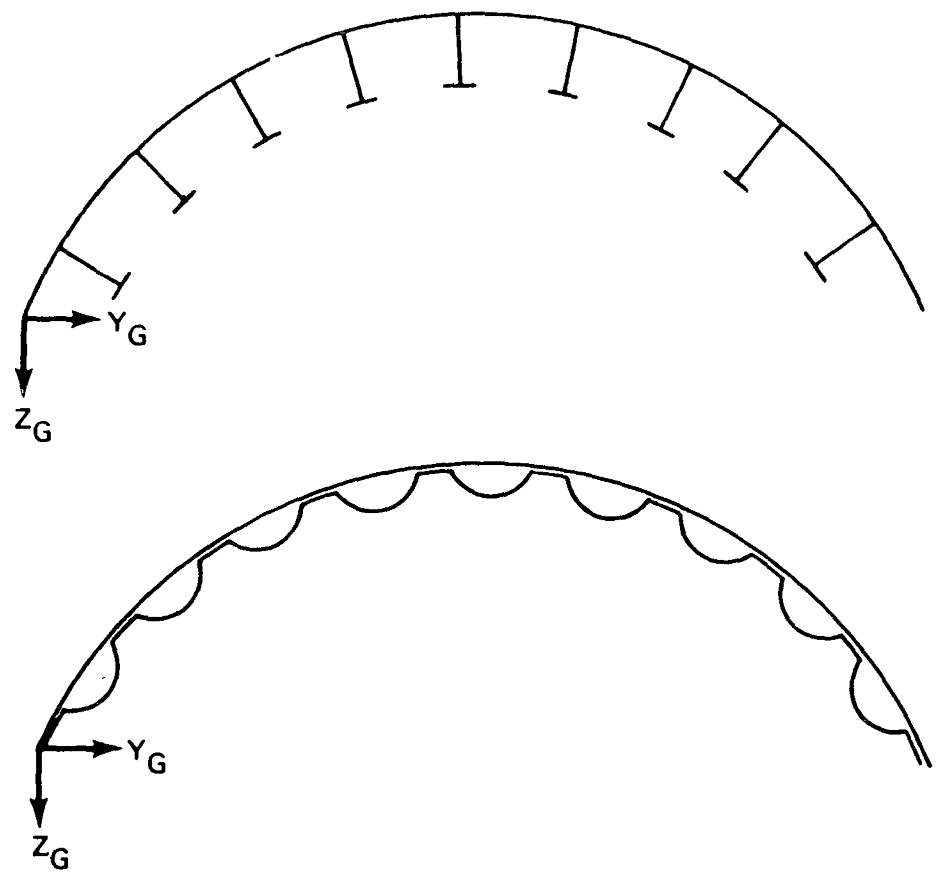
(1) start substructure only
(2) start and end substructures only
(3) start, repeat (one or more) and end substructures.

It should be obvious at this point that panels with no repeatable structural groups can have a maximum of one repeat substructure.

It is recommended that the start substructure be larger of the three substructures, for efficiency reasons in the determinant calculations.



Cross Sections of Flat Panels



Cross Sections of Curved Panels

Figure 2.6 Examples of Repeated Structures

2.5.1 Flat Panel with Repeated Substructures

For a panel with repeated substructures, a reduced version of the actual panel may be specified for input. For example, see Figure 2.7.. (a) is the actual panel and (b) is the reduced panel used for input. The nodal coordinates of 7 to 10 of (b) are input such that they model the end substructure of the actual panel, (a), as if it is moved to the left and attached to the first repeat substructure. Therefore, nodes 7 to 10 of the reduced panel, (b), are related to nodes 23 to 26 of (a), the actual panel. Consequently, nodes 11 to 22 of (a) are not directly included by coordinates in the input, but are implicitly specified through the repeat substructure.

After drawing a sketch of the actual structure, the user must identify the nodes that belong in the three different substructure types. For the start and end substructures, the only limitation is that there must be at least one interior node, a node without any specified boundary conditions, in each substructure. To ensure that the repeat substructure is accurately identified, the substructure corresponding nodes must be identified. The corresponding nodes are those node pairs at which the stiffnesses, independent of element temperatures and loads, are identical. In other words, all elements meeting at corresponding nodes in all repeat substructures must be identical in all respects, including boundary conditions, except for the element temperatures and element loads.

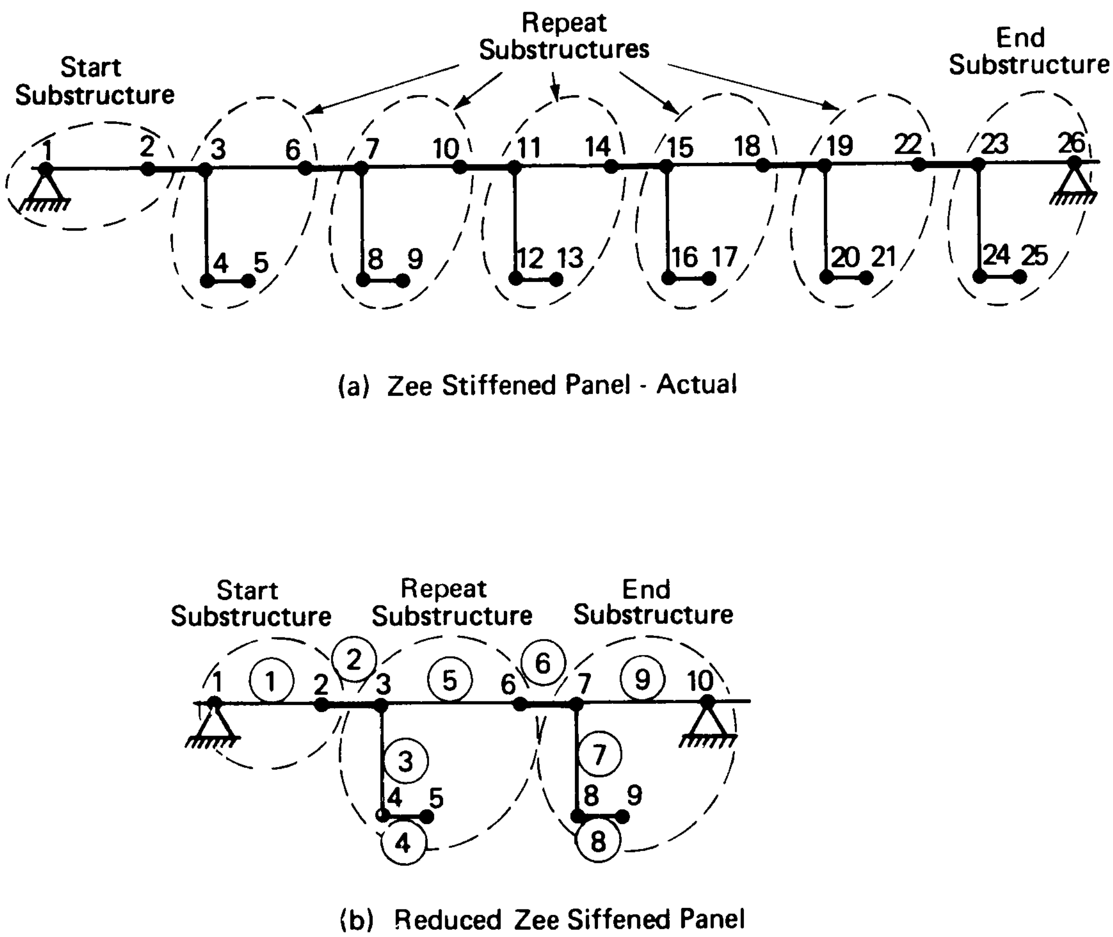
For the example from Figure 2.7(a), inspection shows that nodes 7, 11, 15 and 19 are the corresponding nodes to node 3. Therefore, note 3 is a valid node for the repeat substructure. Similarly, node 6 is a valid node for the repeat substructure with nodes 10, 14, 18, 22 as correspondence nodes; node 4 with 8, 12, 16, 20; and node 5 with 9, 13, 17 and 21. One should note that node 23 is not a corresponding node of node 3 because the specified boundary condition at node 26 results in the stiffness contribution of element 23-26 to node 23 being unequal to the stiffness contribution of element 3-6 to node 3. Thus node 23 may not be included in the repeat substructure.

From this user exercise one can conclude that, a) the substructure unit made up of nodes 3, 4, 5, 6 is a repeat substructure, and b) there are (5) repeat substructures.

Node 2 is included in the start substructure because boundary conditions are specified for node 1. The selection of nodes for the end substructure is obvious at this point.

Although only a reduced version of the actual panel is input, the temperatures or input prestress loads for every element of the actual panel must be specified. This includes all elements in all repeat substructures. At this point, all elements must be assigned to different substructures. Any plate element with both definition nodes lying within a substructure is assigned to that substructure. If one node of an element is in the start substructure and the other node in the repeat substructure, the element is included in the repeat substructure. Plate elements, with one node in the repeat substructure and the other node in the end substructure, are assigned to the end substructure. Since a beam element is defined by a node, the assignments of beam elements should be obvious.

In Figure 2.7(b), element 1 is in the start substructure, elements 2, 3, 4 and 5 are in the repeat substructure and elements 6, 7, 8 and 9 are in the end substructure.



(a) Zee Stiffened Panel - Actual

(b) Reduced Zee Siffened Panel

Figure 2.7 Examples of Repeat Substructures

2.5.2 Substructure Interrelationship Plate Element Pairs

The mode shapes for elements of the panel (not the reduced structure) is provided by the program. These elemental mode shapes are derived from the relative displacements which were determined individually for each node of the actual panel (not just the reduced structure). The previous input information on repeat substructures was adequate to produce (internally) the total structure stiffness from the (input) reduced structure. However, additional information is required to identify elements that connect one repeat substructure to another repeat substructure for the purpose of calculating elemental mode shapes.

From the definition of a repeat substructure, any element, that connects the start substructure to the adjoining repeat substructure, has a corresponding element (topologically similar), that connects the repeat substructure to the end substructure. The requirement then becomes one of identifying;

(a) Each connecting element between the start and repeat substructures
    and
(b) each connecting element (topologically corresponding to (a)) between the repeat and end substructures.

These elements become logically an element pair, and are defined as "interrelationship element pairs".

As an aid to the user, the following steps are recommended (see Figure 2.8).

(1) After encircling the nodes for different substructures as shown in Figure 2.8, identify all element(s) that connects the start substructure to the repeat substructure.

(Elements 3 , 4 , 5 , 6 and 7 of Figure 2.8)

(2) Identify all element(s) connecting the repeat and end substructures. (Elements 13 , 14 , 15 , 16 and 17 of Figure 2.8)

(3) Pair all elements of (1) above, with corresponding elements (topologically similar) from (2) above. For the panel in Figure 2.8, the element pairs are: (3 , 13), (4 , 14), (5 , 15), (6 , 16) and (7 , 17). These are the interrelationship element pairs.

As an additional example, see Figure 2.7(b). The interrelationship element pair is (2 , 6).

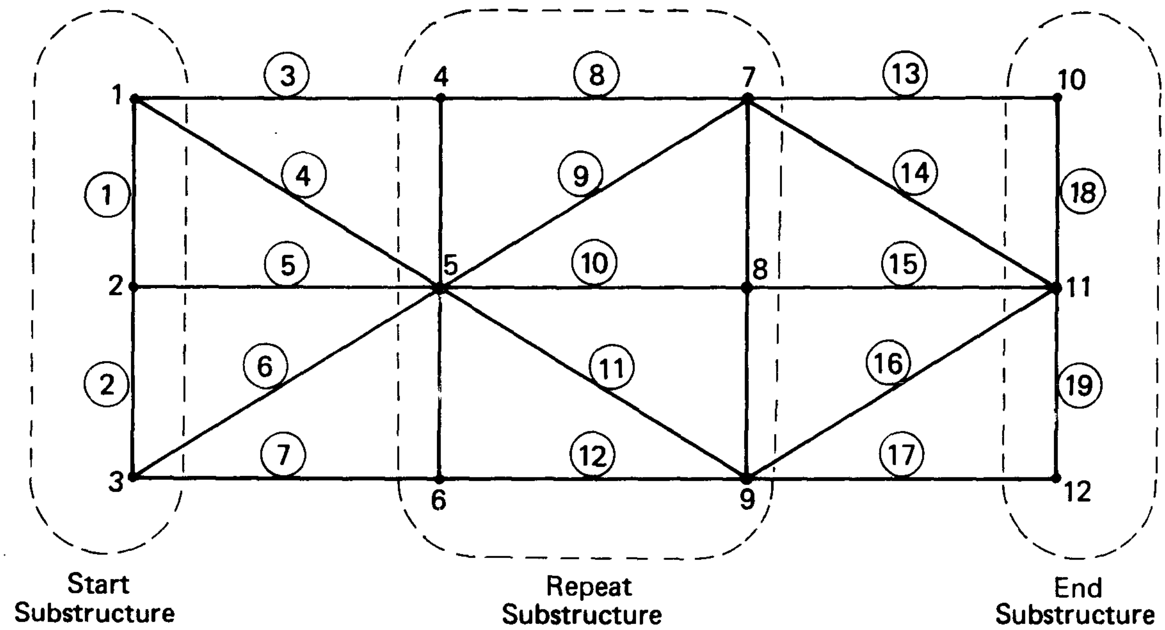


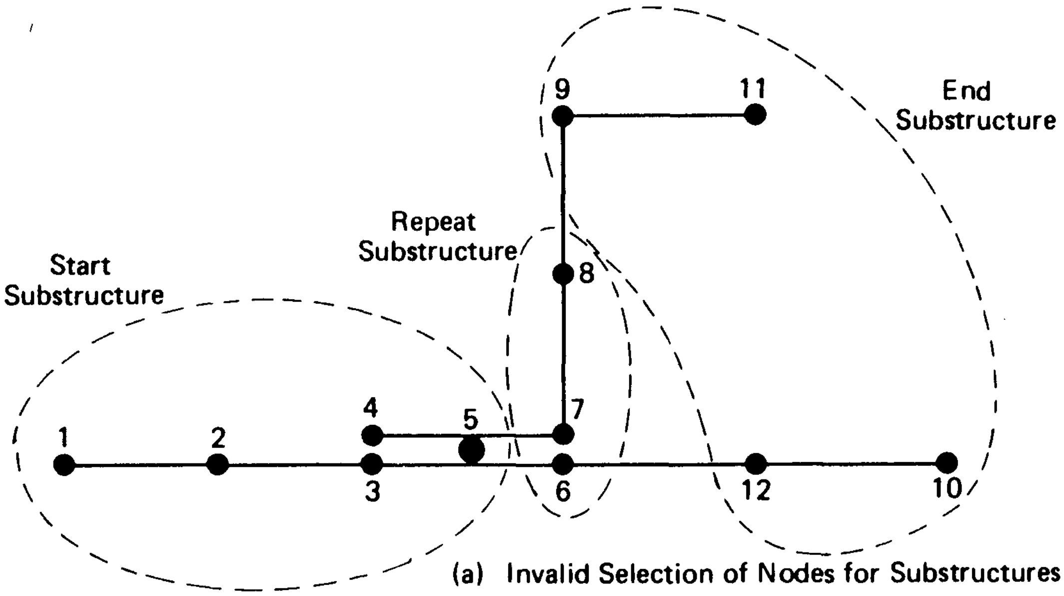
Figure 2.8 Example for Repeat Substructure Interrelationship Element Pairs

2.5.3 Some Restrictions on Substructuring Non-Repetitive Panels

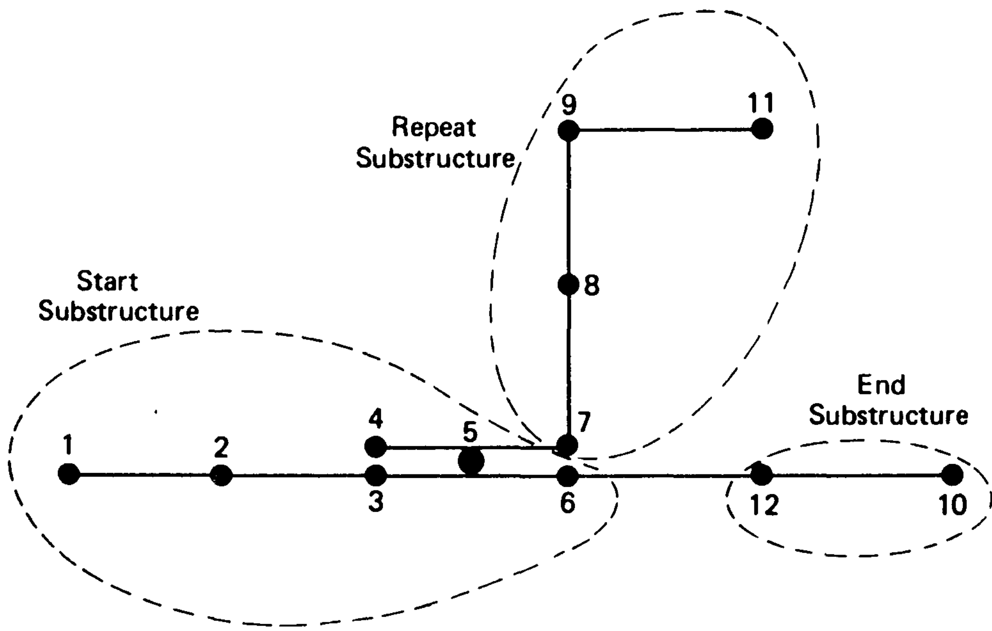
Whenever a panel without repetitive structural groups is idealized with more than one substructure type, care must be exercised in the substructuring process. The panel must be divided such that any one substructure contains only one unconnected piece of structure. To illustrate this, Figure 2.9 is presented. This skin-stringer assembly is divided into three substructures. Node 3 is not attached to node 4, node 6 is not connected to node 7 and node 5 is used to attach the stringer to the skin. In Figure 2.9 (a), the repeat and end substructures defy the restriction stated above, because in the repeat and end substructures, there are two discontinuous or unconnected pieces of structures. In the end substructure, the structure containing nodes 9 and 11 is not attached to the piece of structure that contains nodes 12 and 10, and in the repeat substructure, the piece of structure containing nodes 7 and 8 is not attached to node 6. Therefore, there are two unconnected structural pieces in each of the two substructures, repeat and end. Figure 2.9 (b) is an example of a valid selection of nodes for this problem. Each substructure contains only one continuous piece of structure.

Another restriction is in the input order of the nodes. The nodes should be ordered such that the input list of nodes can be separated into distinct groups, each group related to a different substructure. The start substructure nodes should be input first, repeat substructure nodes, second, and the end substructure nodes last. What is important here is the input or order of nodes, not the user node numbers. If the nodes of Figure 2.9 (b) are input in the same order as the user node numbers, an incorrect data set will result. Nodes 9 through 11 would be out of order. Instead, the input order should be

(1,2,3,4,5,6,7,8,9,11,12,10). The first group of nodes for the start substructure would be (1 to 6), second group for the repeat substructure, (7,8,9,11) and the last group for the end substructure, (12 and 10).



(a) Invalid Selection of Nodes for Substructures



(b) Valid Selection of Nodes for Substructures

Note: Numbers Shown are Users Node Numbers

Figure 2.9 Examples of Node Restrictions in Substructures

2.6 Upper and Lower Bound Loads

The panel upper bound load is required to increase the efficiency of the method used in extracting the lowest eigenvalue. This panel upper bound is defined as the least of the element upper bound loads. An element upper bound load is the buckling load of a plate element with interior sides completely restrained. For a plate element with specified boundary conditions on one side, the upper bound load is the buckling load for the plate with the interior side completely restrained and the exterior side subjected to the specified boundary conditions.

The upper and lower bound loads can be specified as input to PAINT. If the bounds are not specified, an approximate upper bound load will be computed. Since all plate elements are subdivided, the subelement upper bound loads must first be determined. For an interior subelement, they correspond to buckling loads for a subelement completely restrained at both sides. These loads are computed by using the Galerkin method as described in Ref. 2. For an exterior subelement (subelement with a side with specified boundary conditions), the buckling determinant is first formed and then the buckling load is solved. The minimum of the subelement loads is selected to be the upper bound for the element. Finally, the element upper bound is calculated by setting the element buckling determinant to zero. The initial prestress loads are chosen as the element lower bound.

2.7 Mode Shapes

The relative displacements may be computed for the buckling load corresponding to the critical wave number. The relative displacements are computed for each element with respect to its local coordinate system. They can be computed at evenly spaced prescribed points along the width of any plate element. From the output of relative displacements, the mode shape can be hand plotted.

2.8 Modelling of Riveted Connections

This section deals with the modelling of riveted connections. As an example, see Figure 2.10. If the rivet is ignored in the idealization, the stiffener would be assumed to be bonded to the skin. A suggested modelling technique is presented here to more correctly depict the behavior of riveted connections.

The rivet is idealized as a line at nodes 4 and 5. In Figure 2.10(a) the plate elements (2) and (4) are offset at node 4 as shown. Node 5 is equivalenced to node 4 to create an attachment between these nodes. The plate elements (2), (3), (4), and (5) are all joined at node 4, the rivet line, but node 2 of element (2) and node 3 of element (3) are not connected and they are free to deform independently. Nodes 6 and 7 of elements (4) and (5) respectively, are also free to move independent of each other. This modelling is approximate in the sense that the connection between the stiffener and skin is reduced to a line connection.

First, make an initial run with this idealization shown in Figure 2.10(a) and investigate the mode shapes to see if they are feasible. For an example of mode shapes not being feasible, assume that the downward deflection of node 2 in the Z_G direction is greater than the downward deflection of node 3 in the same direction. Wherever this type of physical unreality occurs, join the elements together at these nodes and rerun the problem. For the example cited above, the connection of nodes 2 and 3 is accomplished by making node 2 equivalent to node 3. Offset element (3) as indicated in Figure 2.10(b).

In the original idealization shown in Figure 2.10(a), nodes 2 and 6 seem unnecessary for the first trial analysis. Plate elements 1 and 2 and similarly elements 4 and 8 could be combined into one element. The only reason for including nodes 2 and 6 in the example is to compare the displacements at these locations with nodes 3 and 7 of the stiffener, to see if any unrealistic deflections occur at these points. Actually, the displacements along the junction line between the skin and stiffener top flange should be investigated to check the feasibility of the deformed shapes.

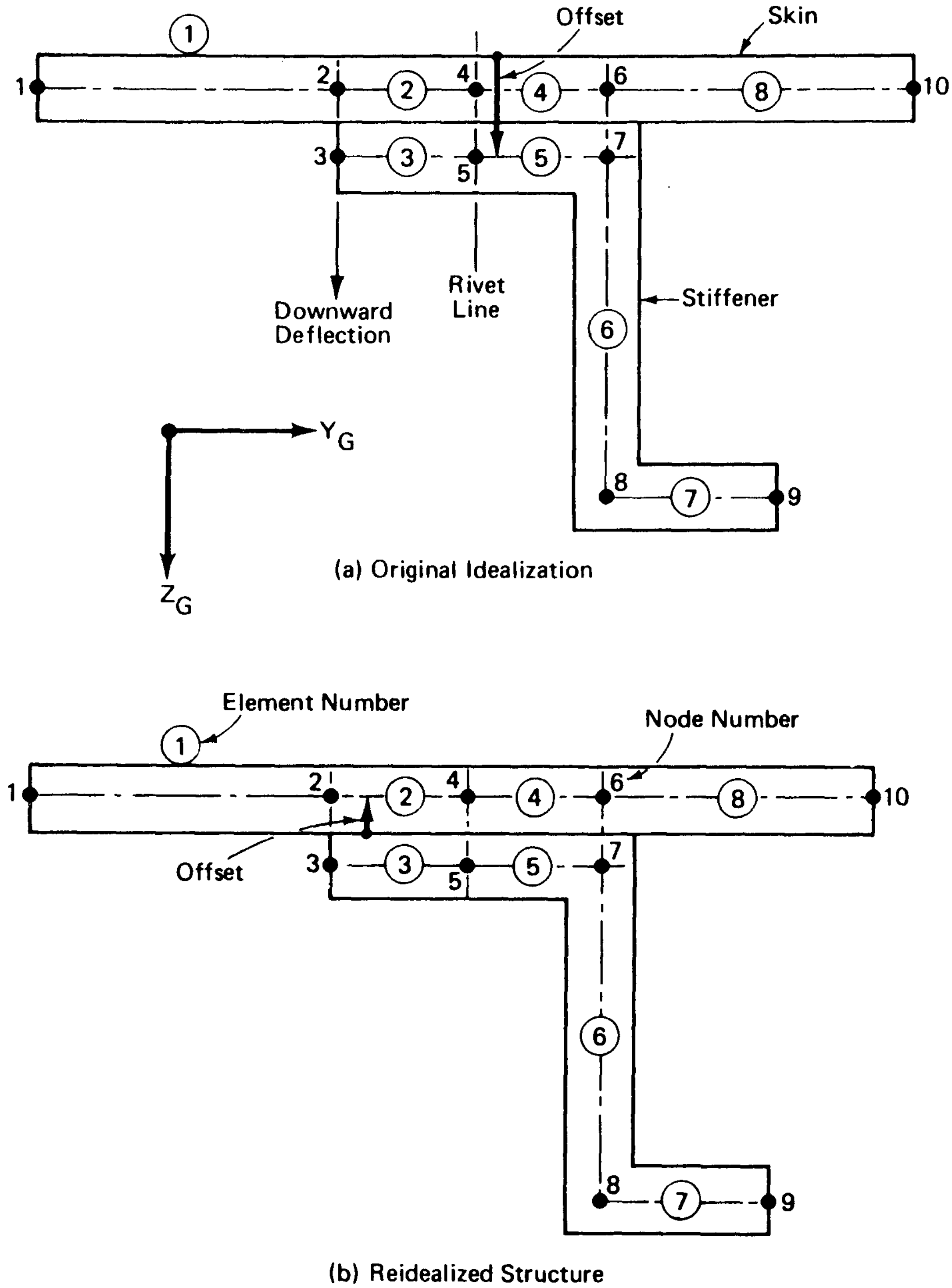


Figure 2.10 Riveted Connection Example

3.0 PROGRAM COMPUTER DETAILS

3.1 Machine Requirements

The BUCLASP3 program is written for the CDC 6600 series computers. It requires the use of a card reader, line printer, disk storage, a minimum of zero and a maximum of one tape drive.

3.2 Operating System

The program runs under the SCOPE 3.1 or KRONOS 2.0 operating systems. All system routines used are assumed to be standard CDC release. With the exception of four special purpose routines in COMPASS, all source routines are coded in CDC FORTRAN IV. The overlay loading feature is used.

Two Langley Research Center routines are used.

JPARAMS	COMPUTER PROGRAMMING MANUAL Volume I, Section K5.1 date 6-9-71

This routine makes certain job parameters available to the user.

SIMEQ	COMPUTER PROGRAMMING MANUAL Volume I, Section F4.1 date 8-1-68

This routine solves a set of linear equations.

3.3 Storage Allocation

The program will LOAD and EXECUTE with a field length of 77000_8. The field length estimate for the program is dependent upon the data set. The space for the buckling determinant is dependent upon the size of the three blocks of the determinant definition.

When the eigenvector and relative displacements or thermal stresses are also wanted the user must take into account in field length allocation that the start substructure, each repeat substructure and the end substructure have to be stored in core.

The data processing overlay prints an estimate of field length required for the other overlays.

3.4 Timing and Output Estimates

Time consumption for one data set depends on various factors.

a. Number of wave numbers investigated.

b. Number of nodes, plate and beam element defined for panel. The size of buckling determinant is proportional to number of unconstrained nodes.

c. Number of plate elements with stiffnesses which are the same.

d. Number of Fourier Harmonics in thermal stress analysis.

e. Number of subelements.

In general, for single data set runs, and with the intermediate printout switches off, the program will generally generate from 30 to 100 pages. The number of wave numbers is a primary factor on the amount of printout. The intermediate printout should be used with care as it can be voluminous.

3.5 Disk File and Tape Utilization

BUCLASP3 uses a maximum of nine files in addition to the standard input and output. The nine files are scratch files used for internal information transfer.

The files referenced are:

(1)	INPUT	Standard Input (Card Reader)
(2)	OUTPUT	Standard Output (Line Printer)
(3)	TAPE1	Scratch File (Binary)
(4)	TAPE2	Scratch File (Binary)
(5)	TAPE11	Scratch File (Binary)
(6)	TAPE12	Scracth File (Binary)
(7)	TAPE13	Scratch File (Binary)
(8)	TAPE14	Scratch File (Binary)
(9)	TAPE15	Scratch File (Binary)
(10)	TAPE16	Scratch File (Binary)
(11)	TAPE17	Scratch File (Binary)

3.6 Control Cards

There are basically three modes of execution, from

(a) source

(b) relocatable binary

(c) absolute binary

In the following, use of specific control cards has been avoided, rather the required sequence to operations is specified. All file names with the exception of BUCLASP are arbitrary. All overlays have the name BUCLASP, thus a file BUCLASP is generated at load time. For the cases above

(a) 1. Obtain a source file, PROG, from permanent storage (Cards, TAPE, permanent disk file, etc.).

2. Compile source file placing relocatable binary on BPRG.

3. Load BPRG.

4. Execute from BUCLASP.

(b) 1. Obtain a relocatable binary file, BPRG, from permanent storage.

2. Load BPRG.

3. Execute from BUCLASP.

(c) 1. Obtain an absolute binary file, BUCLASP, from permanent storage.

2. Execute from BUCLASP.

4.0 PROGRAMMED DIAGNOSTIC MESSAGES

There are two types of error messages. The first is a message followed by a routine name and number. This kind is fatal to further processing so an exit is taken. The second kind is used in the input data processing routines to indicate a data error has been detected, but an attempt will be made to process the rest of the input data. This kind has a message but no number.

Routines which print diagnostic messages:

DATAPRO
FINDIN } Input Data Processing Routines
BLKDEF
TSTIFF
SMOD
SOLVE
TDISPL
TSTRESS
LCNTRL
UPRBND
DM
GAPUPP
DB
SBLKDT
DBLERT
STORE
PRDMTX
PROOT
SOLVV
DISPLAC
FETCHD
READTR
FNLDIS

802 TOO MANY NODES
Card 4 Field 1

804 TOO MANY ELEMENTS
Card 4 Fields 2,3 and 4

806 TOO MANY BEAMS
Card 4 Field 2

808 TOO MANY PLATES
Card 4 Fields 3 and 4

810 BAD EQUIVALENT NODE DATA
E Card

812 BAD INTERRELATIONSHIP ELEMENT DATA
C Card

901 NUMBER OF VALUES, III, IN M-LIST EXCEEDS 30
Cards 6 and 7

902 END OF FILE ENCOUNTERED BEFORE L
L Card was not found

903 NON ELEMENT DATA WAS ENCOUNTERED OUT OF ORDER

904 NUMBER OF NODAL SPRING STIFFNESS SETS EXCEEDED NUMBER OF NODES IN DATA SET

905 NUMBER OF PLATE ELEMENT OFFSET CARDS EXCEEDED THE NUMBER OF PLATE ELEMENTS IN DATA SET

906 NUMBER OF REPEAT SUBSTRUCTURE INTERRELATIONSHIP ELEMENT PAIRS INPUT EXCEEDED MAXIMUM OF IIIII

907 NUMBER OF EQUIVALENT NODE DEFINITION PAIRS INPUT EXCEEDED MAXIMUM OF IIIII

908 INPUT MATERIAL PROPERTY TABLE FAILED

909 INPUT OF THICKNESS TABLE FAILED

910 NUMBER OF NODE DEFINITIONS INPUT, XXXXX, DID NOT AGREE WITH NUMBER SPECIFIED IIIII

911 NUMBER OF ERRORS DETECTED IN PANEL SUBSTRUCTURE DEFINITION = IIIII

912 NUMBER OF PLATE ELEMENTS INPUT EXCEEDED NUMBER SPECIFIED

914 INVALID LOAD OPTION, IIIII, SPECIFIED
Card 5 Field 1

915 INVALID WAVE NUMBER SEARCH OPTION, IIIII, SPECIFIED
Card 5 Field 2

916 IIII ERROR(S) DETECTED IN DATA

917 CURVED PANEL REPEAT SUBSTRUCTURE INTERIOR ANGLE EXCEEDS 180 DEGREES
Card 4 Field 6

918 CURVED PANEL REPEAT SUBSTRUCTURE INTERIOR ANGLE MULTIPLIED BY NUMBER OF REPEAT SUBSTRUCTURES EXCEEDS 360 DEGREES
Card 4 Field 6

919 MATERIAL TABLE INPUT, BUT NO THICKNESS TABLE PRESENT

THICKNESS TABLE INPUT, BUT NO MATERIAL TABLES PRESENT

NUMBER OF MATERIAL TABLES INPUT EXCEEDS MAXIMUM OF III

INVALID PLATE TYPE
Card P Field 5

NUMBER OF LAMINAS EXCEEDS MAXIMUM OF 25
Number of Plates Laminas $\leq$ 25.
Card P Field 7

INVALID PLATE OFFSET SWITCH, III
Card P Field 6

INVALID MATERIAL PROPERTIES INPUT FORMAT OPTION, III
Card P Field 8, or
Card B Field 6

INVALID N_{22} LOAD SELECTION SWITCH, III
Card P Field 9

NUMBER OF RELATIVE DISPLACEMENT SUBDIVISIONS WAS NEGATIVE
Card P Field 10

INVALID MATERIAL TABLE INPUT OPTION, III
Card P Field 11

INVALID BEAM TYPE
Card B   Field 4

NUMBER OF LAYERS EXCEEDED MAXIMUM OF 35
Number of Beam Layers $\leq$ 35

NUMBER OF NODAL CARDS READ EXCEEDS NUMBER DECLARED

ILLEGAL BOUNDARY CONDITION, IIIII ON NODE III

NUMBER OF S CARDS, IIIII, DOES NOT AGREE WITH NUMBERS
OF SPRUNG NODES IIIII

USER ID, IIIII, ON S CARD, IIIII, INVALID

USER ID, IIIII, IN REPEAT SUBSTRUCTURE INTERRELATIONSHIP
PAIR, IIIII, IS INVALID

USER ID, IIIII, IN EQUIVALENT NODE PAIR, IIIII, IS INVALID
Card E

USER ID, IIIII, IN, AAAAA, SUBSTRUCTURE DEFINITION IS INVALID
Card D

NODE1(IIII) DOES NOT PRECEDE NODE2(IIII) OF, AAAAA,
SUBSTRUCTURE DEFINITION
Card D

END NODE(IIII) OF, AAAAA, SUBSTRUCTURE IS NOT CORRECTLY
RELATED TO START NODE(IIII) OF, AAAAA, SUBSTRUCTURE
Card D

NODE(IIII) FOR PLATE(IIII) IS INVALID
Card P   Fields 3 or 4

NODE(IIII) FOR BEAM (IIII) IS INVALID
Card B   Field 3

USER ID, IIIII, FOR PLATE ELEMENT OFFSET SET, IIIII,
IS INVALID
Card F   Field 2

NUMBER OF PLATE ELEMENTS INPUT (IIIII) DOES NOT AGREE
WITH NUMBER SPECIFIED

NUMBER OF BEAM ELEMENTS INPUT (IIIII) DOES NOT AGREE
WITH NUMBER SPECIFIED

IIIIIIIII, IS INVALID NODE NUMBER

NODE I, IIIIIIIII, IS NOT IN START SUBSTRUCTURE

NODE J, IIIIIIIII, IS NOT IN REPEAT SUBSTRUCTURE

NODE, IIIII, IN START SUBSTRUCTURE SHOULD BE PART
OF A REPEAT SUBSTRUCTURE INTERRELATIONSHIP PAIR

BLKDEF

708 IIIII, ERRORS DETECTED IN SUBSTRUCTURE DEFINITION NODE PAIRS

710 PANEL WITH REPEAT SUBSTRUCTURE BUT NO END SUBSTRUCTURE DEFINED

711 SUBSTRUCTURE DEFINITION PAIR IS OUT OF ORDER

713 NO SUBSTRUCTURE DEFINITION NODE INPUT

714 PANEL MATRIX DEFINED IS NOT SQUARE

715 START COLUMN DEFINITION OF SUBSTRUCTURE AAAAAA AND AAAAAA SUBSTRUCTURE IS NOT RELATED PROPERLY
Examine Substructure Definition and Element Connectivity. See Section 2.6.4.

716 END COLUMN DEFINITION OF SUBSTRUCTURE, AAAAAA, AND AAAAAA SUBSTRUCTURE IS NOT RELATED PROPERLY
Examine Substructure Definition and Element Connectivity. See Section 2.6.4.

717 ROW DEFINITION OF SUBSTRUCTURE, AAAAAA AND AAAAAA, SUBSTRUCTURE IS NOT RELATED PROPERLY
Examine Substructure Definition and Element Connectivity. See Section 2.6.4.

718 SUBSTRUCTURE AAAAAA AND SUBSTRUCTURE AAAAAA ARE NOT INTERRELATED PROPERLY
Examine Substructure Defintion and Element Connectivity. See Section 2.6.4.

TSTIFF

1 INSUFFICIENT BLANK COMMON AREA IS AVAILABLE TO CONSTRUCT THE MERGED STIFFNESS MATRIX. INCREASE FIELD LENGTH BY ________ (OCTAL).

SMOD

5 SINGULARITY DETECTED FOR STIFFNESS SUBMATRIX BEING REDUCED

SOLVE

8 SINGULARITY ENCOUNTERED IN ATTEMPT TO PRODUCE STIFFNESS MATRIX

TDISPL

1 INSUFFICIENT BLANK COMMON AREA IS AVAILABLE TO CONSTRUCT THE COMPACTED MERGED STIFFNESS MATRIX FOR THE GLOBAL DISPLACEMENT SOLUTION. INCREASE FIELD LENGTH BY ___________ (OCTAL)

2 THE STIFFNESS MATRIX CANNOT BE DECOMPOSED

TSTRESS

1 INSUFFICIENT BLANK COMMON AREA IS AVAILABLE TO STORE THE LOAD VECTOR FOR THERMAL STRESS CALCULATIONS. INCREASE FIELD LENGTH BY __________ (OCTAL).

LCNTRL

901 Double root could not be successfully bypassed.

902 Zero determinant could not be successfully bypassed.

903 Search for buckling condition did not stabilize in specified number of iterations.

Check for panel being in buckled condition for zero load.

UPRBND

BUCKLED CONDITION element ID, subelement, value (calculated) value (input)

Input load on subelement caused buckled condition

62 LOAD FIELD IS ALL ZERO OR ALL TENSION

64 PANEL WAS DETECTED TO BE IN A BUCKLED CONDITION WITH REPECT TO THE INITIAL LOAD DISTRIBUTION

DM

30 Double root encountered in upper bound calculation

GAPUPP

Matrix reduction failed

DB

906 Matrix block definition faulty

SBLKDT

The MATRIX HAS A ZERO ROW

MATRIX SIZES OR RELATIVE POSITIONS ARE INCOMPATIBLE

Zero Determinant at Block xxx

DBLERT

Double Root Detected

STORE

22 Node number not found in substructure row definitions

24 Node number not found in substructure column definitions

PRDMTX

5 Element nodal interconnective matrix singular

PROOT

ZARK failed to converge in the maximum number of iterations specified

PROOT

ZARK failed - A zero in the path of a subsequent one.

Complex root found that is not one of a conjugate pair

SOLVV

8	SINGULARITY ENCOUNTERED IN ATTEMPT TO PRODUCE STIFFNESS MATRIX

DISPLAC

INSUFFICIENT CORE IS AVAILABLE TO CONSTRUCT THE STIFFNESS MATRIX FOR THE EIGENVECTOR SOLUTION INCREASE FIELD LENGTH BY ________

THE STIFFNESS MATRIX CANNOT BE DECOMPOSED

FETCHD

14	Attempt fetch a non-existent nodal displacement component

READTR

10	ID on nodal transformation invalid
12	ID on elemental transformation invalid

FNLDIS

20	Attempt to invert elemental tranformation matrix failed.

5.0 RESTRICTIONS

The following restrictions apply to this version of the program.

5.1 Analysis Oriented Restrictions

a. Prebuckling deformations are ignored and linear theory (small deformations and linear elastic materials) is used.

b. Each layer is orthotropic with respect to plate axes.

c. Plate elements have constant thicknesses.

d. The cross-section is uniform in the axial direction.

e. Loaded edges of each element forming the cross-section are simply supported.

f. The arc of a curved plate element has to be less than or equal to 180 degrees.

g. Buckling load will not be computed for a structure already buckled by the input loads.

h. The temperature distribution in the longitudinal direction is a constant.

i. Only plate in-plane biaxial loads and beam axial loads are considered as applied loads in the buckling formulation. Further, they are treated as constant values.

j. For the input loads option, plate biaxial loads are constants in each subelement of a plate element.

5.2 Programming Oriented Restrictions

a. Maximum number of elements definable in three substructures is 35, and the maximum number of nodes is 35.

b. Maximum number of types of plate elements is 10. These are of the same type in the sense that their lamina stiffness matrices, are of the same content.

c. The maximum number of layers is 25 for plate elements.

d. Maximum number of beam elements is 30.

e. The maximum number of layers is 35 for beam elements.

f. Two real roots of the determinant expression det (DT) = 0 are considered double if they differ by less than 0.00003%.

g. The imaginary part of the complex roots of the determinant expression det (DT) = 0 is exactly set to zero if its numerical value is less than 10^{-6}, or when it is less than 10^{-5} times the real part of the number. A similar test applies to the real part of the number.

h. It is assumed that no coupling exists between bending and stretching when all of the elements of the B-matrix are less than 1.0.

i. Maximum number of wave numbers that can be investigated in one data set is 30.

j. The minimum number of elements is either 2 plates or 1 plate and 1 beam.

k. There must be at least 1 interior node in each substructure type.

l. Node restrictions in substructues; see Section 2.5.

m. An element cannot have nodes both in the start and end substructures, which means closed cylinder problems must be done with a single substructure.

n. Number of buckling subdivisions per plate is between 2 and 20.

o. Total number of elements definable with thermal or external loading is 100.

p. Each substructure is restricted to 14 elements.

q. Thermal stress calculation is limited to twelve points in the x-direction and is set to five in the y-direction.

5.3 Mathematical Oriented Restrictions

In the buckling calculation the process is done strictly incore where the number of repeat substructures is arbitrary, but will be limited in practice by the accumulation of rounding errors.

The eigenvector computation requires that the buckling load be well isolated. Problems which buckle without a determinant change of sign will have multiple eigenvectors for the buckling load.

The program appears to have some modelling restrictions relative to use of high wave numbers in buckling calculations. See appendix for details.

6.0 PROGRAM INPUT

The data input to this program consists only of cards, and no data tapes are required.

6.1 Input Data Format

Fields of 5 or less are right adjusted integers. Fields of 10 are floating point numbers with format F10.0.

CARD 1 (8A10)

Columns	Column 1 must be blank.
2-80	Title of run. Any characters anywhere in columns. This title is printed out in several strategic places in the output for the purpose of identification.

CARD 2 (16I5) Intermediate Print Control (IPC) Array

The intent of the options on this card is for diagnostic checking.

Columns

1-5	IPC(1) = 1	Print intermediate results (1)
	= Blank	Suppress print
	This option prints out control lists obtained from input data.	
6-10	IPC(2) = 1	Print intermediate results (2)
	= Blank	Suppress print
	This option prints out the p roots of the determinant expression det (DT) = 0 (equilibrium equations) during the upper bound calculation.	
11-15	IPC(3) = 1	Print intermediate results (3)
	= Blank	Suppress print
	This option prints out the elemental and merged stiffness matrices along with the determinant calculation information during the upper bound calculation.	

Columns

16-20	IPC(4) = 1	Print intermediate results (4)
	= Blank	Suppress print

This option prints out information about the element upper bound initial estimates and the actual upper bound.

21-25	IPD(5) = 1	Print intermediate results (5)
	= Blank	Suppress print

This option prints out the p roots of the determinant expression det (DT) = 0 (equilibrium equations) during the panel buckling calculation.

26-30	IPC(6) = 1	Print intermediate results (6)
	= Blank	Suppress print

This option prints out the elemental matrices during the panel buckling calculation.

31-35	IPC(7) = 1	Print intermediate results (7)
	= Blank	Suppress print

This option prints out the merged stiffness matrices and determinant calculation information during the panel buckling calculation.

36-40	IPC(8) = 1	Print intermediate results (8)
	= Blank	Suppress print

This option prints out the compacted stiffness matrix, the element p roots and the element ω_i.

41-45	IPC(9) = 1	Print intermediate results (9)
	= Blank	Suppress print

This option prints out the p roots of the determinant expression det (DT) = 0 (equilibrium equations) during the thermal stress calculation.

Columns			
46-50	IPC(10) = 1	Print intermediate results (10)
	= Blank	Suppress print
	This option prints out the element matrices during the thermal stress phase.	
51-55	IPC(11) = 1	Print intermediate results (11)
	= Blank	Suppress print
	This option prints out the merged stiffness matrix.	
56-60	IPC(12) = 1	Print intermediate results (12)
	= Blank	Suppress print
	This option prints the merged right-hand side vector, the calculated global deflection vector and other check prints in the deflection calculation.	
61-65	IPC(13) = 1	Print intermediate results (13)
	= Blank	Suppress print
	This option turns on the check prints in the stress calculation.	
66-70	IPC(14) = 1	Print intermediate results (14)
	= Blank	Suppress print
	This option prints out subelement force and deflection matrices during buckling calculation	

CARD 3 (16I5) Program Control Array

Columns

1-5	JPC(1)	= 1	Calculate panel upper bound only
		= 0 (Blank)	Proceed as normal
6-10	JPC(2)	= 0 (Blank)	No relative displacements
		= 1	Compute relative displacements
11-15	JPC(3)	= 1	Data check only is performed
		= 0 (Blank)	Non data check only mode
16-20	JPC(4)	η	Number of iterations allowed in buckling calculation, where $1 \leq \eta \leq 100$
		= Blank	Number will be defaulted to 100
21-25	JPC(5)	η	Number of iterations used in eigenvector calculation, where $4 \leq \eta \leq 100$
		= Blank	Number will be defaulted to 4

Option should be used with care. Can be used to find multiple eigenvectors for problems with coincident roots by running problem with η iterations and then with $\eta + 1$ iterations.

26-30	JPC(6)		Default plate element thermal input option
		= 1	Input T_{pz} (constant) at mid-plane of each lamina
		= 2	Input element coefficients A_z, B_z, C_z of the equation $T_{pz} = A_z + B_z\bar{z} + C_z\bar{z}^2$ for each element. $\bar{z}$ is along the local z axis of the element and its origin is at the outer surface of the element.

Columns			
31-35	JPC(7)		Default value for number of plate element subelements used in buckling analysis. Value must be greater than 1 and less than or equal 20. To specify number of subelements other than default value, see Card P.
36-40	JPC(8)	=	First Fourier harmonic (odd number) for output of stresses and displacements
41-45	JPC(9)	=	Last Fourier harmonic (odd number) for output of stresses and displacements. (The stresses and displacements are summed from 1 and are printed for harmonics between specified limits)
46-50	JPC(10)		Output option for stresses and displacements
		= NUMX	where NUMX = number of equally spaced points along the x-axis for the output of stresses and displacements
		- NUMX	Table of NUMX values for output of stresses and displacements will be given on Card 8 (To be used when output at points unequally spaced along the x-axis is desired) NUMX $\leq$ 12

CARD 4 Problem Characteristics

Columns

1-5	Number of Nodes in the section (i.e., in start substructure, one repetitive substructure and the end substructure)
6-10	Number of Beam elements in the section
11-15	Number of Flat Plate elements in the section
16-20	Number of Curved Plate elements in the section
41-50	Length of the section
51-60	Transverse Load or Strain value
61-70	Biaxial Load Ratio for first plate element Input only when this option is selected.
71-75	Maximum Fourier harmonic used to describe constant thermal load along local x-axis (Use only odd numbers).

For the transverse load or strain value, input a negative value for tension and a positive value for compression. Biaxial load ratios are computed with the same sign convention as above.

CARD 5 Analysis Options

Columns

1-5		Load/Stress Options
	= 4	Calculate Thermal Stresses only (see Section 1.1).
	= 5	Buckling due to N_{11} axial load under a thermal environment (see Section 1.2).
	= 6	Buckling due to thermal effects only. Critical temperature ratio is computed (see Section 1.2).
	= 7	Buckling due to $\bar{N}_{11}$ (force/length) for a panel that is initially prestressed by specified biaxial loads. (See Section 1.3).
	= 8	Buckling analysis, where the critical load ratio is computed. See Section 1.3.
6-10	MOPT	Option control for the loop on the longitudinal wave number M.
	= 1	Start the loop at wave number MMI and loop until a minimum load is found, then interrupt (Max. 30 loops)
	= 2	Start the loop at wave number MMI and loop to wave number MMA (Max. 30 loops)
	= 3	Start the loop at first value of M-list and loop through M-list until a minimum load is found, then interrupt (M-list must be input on Cards 6,7) (Max. 30 loops)
	= 4	Start the bop at first value of M-list and loop through M-list. (M-list must be input on Cards 6,7) Max. 30 loops)
11-15	MMI	Starting value for the loop on the longitudinal buckling wave number M Set = 1 for options 3 and 4
16-20	MMA	End value for the loop on the longitudinal buckling wave number M Set = number of values in M-list for options 3 and 4

Columns

21-25	NLW	Lower Limit for root searching criteria (If left blank, NLW is defaulted to 0)
26-30	NUP	Upper Limit for root searching criteria. If left blank, NUP is defaulted to 1 NLW $\geq$ 0, NLW < NUP. The program does a complete solution of the data for each root searching criteria $\eta/\eta+1$ where NLW $\leq \eta <$ NUP. (η is the number of roots below the trial load.)
31-35		Default number of element subdivisions for relative displacement calculation (defaulted to 5, if left blank)
41-50	SLW	Lower bound (first plate element) for search interval (defaulted to 0.0, if left blank)
51-60	SUP	Upper bound (first plate element) for search interval. If left blank an upper bound is calculated for the structure for each M value. If specified SLW SUP. Note that the same SLW, SUP pair is used for every M value to be searched.

See Section 1 for discussion of load options 4 to 8. Refer to Section 2.6 for discussion of upper bounds. For a discussion of the root searching criteria, see Section 6.1 of Reference 2.

CARD 6	M-list (limited to 30 values) (List of wave numbers)
Columns	
1-5	First value of M-list
6-10	Second value of M-list
. . . .	
75-80	Sixteenth value of M-list
CARD 7	M-list (continued) (Use this card if necessary; if not omit)
1-5	Seventeenth value of M-list
. . . .	
65-70	Thirtieth value of M-list

CARD 8 Table input for output of stresses and displacements - Omit if JPC(10) ≥ 0 or blank

Columns

1-10	First x-coordinate
11-20	Second x-coordinate
.	.
.	.
.	.
71-80	Eigth x-coordinate

CARD 9

Columns

1-10	Ninth x-coordinate
11-20	Tenth x-coordinate
21-30	Eleventh x-coordinate
31-40	Twelfth x-coordinate

CARD T-1 Lamina Thickness Table

Columns

1-5	Letters "THICK"
11-80	..., ..., value, .../ where value may be ± nnn.nnn or ± n.nnnn E ± nn Number of significant digits is limited to 14

The table is terminated by the character slash (/). If the entries of a table exceed one card, the table may be put on more cards using columns 11-80 (columns 1-10 blank) with the last table value followed by a slash. The values in the table are delimited by commas and physical end of card.

Omit card if Table option not used for element property input. See Section 6.4 for discussion of table use.

Note: Only one thickness table is allowed per data set.

CARD T-2 Lamina Material Properties Table

Columns	
1-5	Letters "TABLE"
9-10	Table Number
11-80	..., ..., value, .../

Same rules for this table as the one on CARD T-1

Omit card if Table option is not used for element property input. See Section 6.4 for discussion of table use.

Table Lengths

Element	Length
Plate	4
Rectangular Beam	3
Circular Beam	2

CARD C   Substructure Interrelationship Element Pair

Columns

1-1	Letter "C"	
3-5	Element i	Pair 1 (this card)
8-10	Element j	
. . .	Element i of start-repeat substructure is interrelated to Element j of repeat-end substructure	
73-75	Element i	Pair 8 (this card)
78-80	Element j	

Repeat this card for each set of 8 interrelationship element pairs until all interrelationship element pairs have been input.

Note: Interrelationship elements must be included if the number of repeat blocks $\geq$ 2. See Section 2.5.2 for discussion.

CARD E Equivalent Nodes

Columns

1-1	Letter "E"	
3-5	Node i	Pair 1 (this card)
8-10	Node j	
.		
.		
.		
73-75	Node i	Pair 8 (this card)
79-80	Node j	

Repeat this card for each set of 8 equivalent node pairs until all equivalent node pairs have been input. See section 6.2 for discussion of equivalent nodes.

Note: Equivalent nodes must be interior nodes. This card is used to specify those nodes which move together structurally. Omit this card if no equivalent nodes exist.

CARD N Nodal Definition

Columns

1-1	Letter "N"
3-5	User Node Number
10-10	Nodal Boundary Condition
	= Blank Interior
	1 Simple Support
	2 Clamped
	3 Free
	4 Sprung (Card S must follow)
21-30	Y - coordinate of node in right-handed global coordinate system
31-40	Z - coordinate of node in right-handed global coordinate system

Internal node number is determined by input position, i.e., first node input is internal node one, etc.

CARD D Panel Substructure Definition

Columns

1-1	Letter "D"
3-5	The number of substructures that the buckling determinant is divided into. This includes the start and end substructures plus the repeat substructures.
8-10	User node number which the Lowest Internal Node Number in Start Substructure
13-15	User node number which is the Highest Internal Node Number in Start Substructure
18-20	User node number which is the Lowest Internal Node Number in Repeat Substructure
23-25	User node number which is the Highest Internal Node Number in Repeat Substructure
28-30	User node number which is the Lowest Internal Node Number in End Substructure
33-35	User node number which is the Highest Internal Node Number in End Substructure

A substructure is left undefined by not specifying substructure definition node pair.

Permissible Combinations

Start Substructure Only

Start and End Substructures Only

Start, Repeat (one or more) and End Substructures

It is recommended that the start substructure be larger of the three substructures, for efficiency reasons in the determinant calculations. Note: See card N for definition of Internal Node Number.

CARD S Nodal Spring Stiffness

Columns

1-1	Letter "S"
3-5	User Node Number
11-20	Local w component for node
21-30	Local θ component for node
31-40	Local v component for node
41-50	Local u component for node

See Section 2.4 for discussion of sprung nodes.

Omit this card if there are no sprung nodes.

CARD F Plate Element Offset

<u>Columns</u>

1-1		Letter "F"
3-5		User Plate Number
11-20	OFF1	Offset z_0 in the local z direction at the starting end $(y = -b/2)$ of the plate element, measured positive in the positive z direction, from the negative surface of the element to the grid.
21-30	OFF2	Offset y_0 in the local y direction at the starting end $(y = -b/2)$ of the element, measured positive in the positive y direction, from the end of the element to the grid.
31-40	OFF3	Offset z_0 at the end $y = +b/2$ of the plate element. Measured similarly to OFF1.
41-50	OFF4	Offset y_0 at the end $y = +b/2$ of the plate element. Measured similarly to OFF2.

Omit this if no plate offsets exist.
See Section 2.3 for discussion of offsets.

CARD P Plate Definition

<u>Columns</u>

1-1	Letter "P"
3-5	User Plate Number
8-10	Plate definition Node I
13-15	Plate definition Node J
20-20	Plate element type = 1 Flat Plate 2 Curved Plate
25-25	Element Offset Switch = 0 (Blank) No offsets for this plate 1 Element has offsets
29-30	Number of laminas in element
35-35	Input type for element material properties = 0 (Blank) P-1 or P-2 cards are used for material property input 1 Material properties are input through tables
40-40	N_{22} load selection switch = 0 (Blank) The N_{22} load is applied this plate ("affected") 1 This plate will have an effective N_{22} load of ZERO (Available for options 1,2,3)
43-45	Number of subdivisions used in relative displacement calculation. If left blank, the default number specified on Card 5 is used.
50-50	Input option for material properties = 0 (Blank) Engineering constants E_{11}, E_{22}, ν_{12}, G_{12} are specified 1 Lamina stress-strain matrix Q is specified

Columns

51-55 Local value for plate thermal input (Required for LOADOP = 4,5,6)

= 0 Default option is used

1 Input T_z at mid-plane of each lamina (constant)

2 Input element coefficients A_z, B_z, C_z

3 No thermal input

56-60 Load distribution input option (Required for LOADOP = 7,8)

= 0 Load input present

1 No load input

61-65 Substructure to which the element is assigned. If both nodes are in a substructure, then the element is in that substructure, otherwise:

If one node is in the start substructure and one node is in the repeat substructure, then the element is in the repeat substructure.

If one node is in the repeat substructure and one node is in the end substructure, then the element is in the end substructure.

If one node is in the start substructure and one node is in the end substructure, then the element is in the end substructure.

(Required for LOADOP = 4 - 8)

1 = Start substructure

2 = Repeat substructure

3 = End substructure

66-70 Number of subelements used in buckling calculation. (If left blank, default value is used.)

71-80 Curved Plate Element Radius (see Section 2.2.1)

CARD P-1 Plate Thickness and Material Properties

Columns

1-10	T	Thickness of lamina
11-20	E_{11}	E- modulus for direction 1
21-30	E_{22}	E- modulus for direction 2. E_{22} need not be entered for isotropic laminas.
31-40	RNUA	Poisson's ratio, ν_{12}
41-50	G_{12}	G- modulus

The subscript 1 denotes the longitudinal axis and the subscript 2 the transverse axis of the plate local coordinate system.

CARD P-2 Plate Lamina Thickness and Q_{ij} Matrix

Columns	
1-10	Thickness of lamina
11-20	Q_{11} element of lamina Q_{ij} matrix
21-30	Q_{12} element of lamina Q_{ij} matrix
31-40	Q_{22} element of lamina Q_{ij} matrix
41-50	Q_{66} element of lamina Q_{ij} matrix

Q_{ij} are the elements of the stress-strain matrix. See equation (4.3) of Reference 2.

CARD P-3 Plate Temperature Distribution Coefficients

Columns

1-10	TX	T_{px}	Constant value to describe the temperature distribution in the x-direction.
11-20	TYA	a_y	for $T_{py} = a_y + b_y.y + c_y.y^2$,
21-30	TYB	b_y	temperature variation in the local y-direction
31-40	TYC	c_y	
41-50	TZA	A_z	for $T_{pz} = A_z + B_z\bar{z} + C_z\bar{z}^2$,
51-60	TZB	B_z	temperature variation in the local z-direction.
61-70	TZC	C_z	

(Omit columns 41 to 70 if T_{pz} is input at mid-plane)

The P-3 card follows the P-1 or P-2 (or equivalent) for a plate element. For elements in the repeat substructure, the sequence of P-3 and P-4 cards must be repeated for each repeat substructure.

CARD P-4 Plate Lamina Thermal Properties

Columns

1-10	ALPHX	Linear Thermal Coefficient of Expansion in the x direction
11-20	ALPHY	Linear Thermal Coefficient of Expansion in the local y direction
21-30	TZ	Value for T_{pz}

(Omit columns 21-30 if A_z, B_z, C_z values are input)
There must be a P-4 card input for each lamina in plate.

CARD P-5 N_{11} Load Distribution Input

<u>Columns</u>

1-10 N_{11} value for first subelement

11-20 N_{11} value for second subelement

21-30 N_{11} value for third subelement

31-40 N_{11} value for fourth subelement

41-50 N_{11} value for fifth subelement

51-60 N_{11} value for sixth subelement

61-70 N_{11} value for seventh subelement

71-80 N_{11} value for eigth subelement

For elements with more than eight subelements, repeat the P-5 card until all N_{11} values are input for all subelements. (Limit of 20 subelements per element)

For elements in the repeat substructure, there must be a group of P-5 cards for each repeat substructure.

The tensile loads are input as positive values and the compressive loads as negative values.

CARD P-6 N_{22} Load Distribution Input

<u>Columns</u>

1-10 N_{22} value for first subelement

11-20 N_{22} value for second subelement

21-30 N_{22} value for third subelement

31-40 N_{22} value for fourth subelement

41-50 N_{22} value for fifth subelement

51-60 N_{22} value for sixth subelement

61-70 N_{22} value for seventh subelement

71-80 N_{22} value for eigth subelement

For elements with more than eight subelements, repeat the P-6 card until all N_{11} values are input for all subelements. (Limit of 20 subelements per element)

For elements in the repeat substructure, there must be a group for P-6 cards for each repeat substructure.

Tensile loads are input as positive values; compressive loads as negative values.

CARD B Beam Definition

<u>Columns</u>

1-1	Letter "B"
3-5	User Beam Number
8-10	Beam Definition Node
13-15	Type of Beam
	= 1 General
	2 Rectangular (may be laminated)
	3 Circular (may be laminated)
18-20	Number of layers if laminated
25-25	Input type for element material properties
	= 0 (Blank) B-1, B-2 or B-3 cards are used for material property input
	1 Material properties are input through tables
26-30	Thermal Input Option
	= 0 Thermal Data is input for this element (i.e., a B-4, B-5, B-6, or B-7 card is input)
	1 No Thermal Data
31-35	Load Input Option
	= 0 Loads are input for this element (i.e., a B-8 card is input)
	1 No load data
36-40	Substructure to which the element is assigned (Required for LOADOP = 4-8. See P card for explanation.)

41-50	Angle between the local y-axis of beam element and the global y-axis (measured clockwise, from the global y-axis)
51-60	Area of beam (Option 1) Beam element definition node must be equivalenced to a node of plate element.

CARD B-1 General Beam Properties

Columns

1-10	E-modulus of beam element in longitudinal direction
11-20	G-modulus of beam element material
21-30	Moment of inertia about local y-axis
31-40	Moment of inertia about local z-axis
41-50	Warping constant for beam element about shear center
51-60	Torsion constant of bead or lip about shear center
61-70	y distance measured from the shear center to the centroid of the beam (measured parallel to local y axis)
71-80	z distance measured from the shear center to the centroid of the beam (measured parallel to local z axis)

See Section 2.2.2 for description of local coordinate system.

CARD B-2 Rectangular Beam Lamina Thickness and Material Properties

Columns

1-10	Lamina Thickness
11-20	E-modulus of lamina in longitudinal direction
21-30	G-modulus of lamina material
31-40	Width of beam element If the width of all lamina is the same, then only the width for the first lamina need be specified.

CARD B-3 Circular Beam Lamina Radius and Material Properties

Columns

1-10 Lamina Outer Radius

11-20 E-modulus of lamina in longitudinal direction

21-30 G-modulus of lamina material

For a tube element, input the hole as the first lamina with zero E and G.

CARD B-4 General Beam Thermal Loads

<u>Columns</u>

1-10	MTY	Thermal Moment about the local y axis, M_{yT}
11-20	MTZ	Thermal Moment about the local z axis, M_{zT}
21-30	P1T	Thermal axial load - P_T

For elements in the repeat substructure, there must be a B-4 card input for each repeat substructure for the element.

The B-4 card follows the B-1 card for a beam.

See equation (4.53) to (4.55) of Reference 2.

CARD B-5 Rectangular Beam Temperature Distribution Coefficients

Columns

1-10	TXO	T_{bx}	constant value to describe the temperature distribution in the x-direction
11-20	TAZ	a_z	for $T_{bz} = a_z + b_z \cdot z + c_z \cdot z^2$, temperature variation in the local z-direction
21-30	TBZ	b_z	
31-40	TCZ	c_z	

The B-5 card follows the B-2 (or equivalent) for a beam. For elements in the repeat substructures, the sequence of B-5 and B-6 cards must be repeated for each repeat substructure.

CARD B-6 Rectangular Beam Lamina Thermal Properties

Columns

1-10	ALPHX	Linear Thermal Coefficient of Expansion in the x-direction
11-20	TY	T_{by} - constant value to describe temperature distribution in the local y-direction

There must be a B-6 card input for each lamina of the beam. The B-6 card(s) for a beam follow the beam's B-5 card.

CARD B-7 Circular Beam Lamina Thermal Properties

Columns

1-10	ALPHX	Linear Thermal Coefficient of Expansion in the x-direction
11-20	TR	Lamina Temperature

The B-7 card(s) for a beam for the B-3 (or equivalent) for the beam. There must be a B-7 card input for each lamina of the beam.

For elements in the repeat substructures, there must be input a group of B-7 cards for each repeat substructure.

CARD B-8 Beam Load Input

Columns

1-10 Axial load for beam, tension = (+) and compression = (-).

The B-8 card follows the B-1, B-2 (or equivalent), or B-3 (or equivalent) for a beam. For elements in the repeat substructure, there must be a B-8 card input for each repeat substructure.

CARD L Last Card of Data Set

<u>Columns</u>

1-1 Letter "L"

This card must terminate each data set.

6.2 Use of Equivalent Nodes

Equivalent nodes are used to cause two nodes to move together structurally. Beam are attached to plate elements so beam definition nodes must always be made equivalent to plate nodes. Care must be exercised so that (1) the use of equivalent nodes does not alter a substructure definition, and (2) a node that is a left (right) node of an equivalent pair does not appear as a right (left) node of a subsequent equivalent pair. See examples below:

	not permissable	permissable
(a)	$n_1 \rightarrow n_2$ $n_2 \rightarrow n_3$	$n_1 \rightarrow n_2$ $n_3 \rightarrow n_2$
(b)	$n_1 \rightarrow n_2$ $n_3 \rightarrow n_1$	

6.3 Data Stacking

LOADOP = 1, 2, 3

CARD	ORDER		
1	1		
2	2		
3	3		
4	4		
5	5		
6	Next if required		
7			
N			
D			
T-1			
T-2			
C			
E	Omit any cards that are inapplicable		
S			
F			
P			
P-1 (or equivalent)			All plate definition cards
or (not both)		Repeat for	
P-2 (or equivalent)		each lamina	
B			
B-1			All beam definition cards
B-2 (or equivalent)		Repeat for	(Omit if no beams)
B-3 (or equivalent)		each lamina	
L			Last card in data set

Repeat this order of card stacking for multiple data sets.

LOADOP = 4

CARD	ORDER
1	1
2	2
3	3
4	4
5	5

8
9 } Next if required

N

D

T-1
T-2
C
E
S
F } Omit any cards that are inapplicable.

P

P-1 (or equivalent) or
P-2 (or equivalent) } Repeat for each lamina

P-3
P-4 Repeat for each lamina } Repeat for elements in Repeat Substructure

} Plate Definition Cards

B

B-1
B-4

or

B-2 (or equivalent) Repeat for each lamina
B-5
B-6 Repeat for each lamina } Repeat for elements in Repeat Substructure

or

B-3 (or equivalent) Repeat for each lamina
B-7 Repeat for each lamina } Repeat for elements in Repeat Substructure

} All beam definition Cards (Omit if no beams)

LOADOP = 5 or 6

CARD	ORDER		
1	1		
2	2		
3	3		
4	4		
5	5		
6	Next if required		
7			
N			
D			
T-1	Omit any cards that are inapplicable		
T-2			
C			
E			
S			
F			
P			Plate Definition Chart
P-1 (or equivalent) or	Repeat for each lamina		
P-2 (or equivalent)			
P-3		Repeat for elements in Repeat Substructure	
P-4 Repeat for each lamina			
B			All beam definition Cards (Omit if no beams)
B-1			
B-4			
or B-2 (or equivalent)	Repeat for each lamina		
B-5		Repeat for elements in Repeat Substructure	
B-6 Repeat for each lamina			
or B-3 (or equivalent)	Repeat for each lamina		
B-7 Repeat for each lamina		Repeat for elements in Repeat Substructure	

LOADOP = 7 or 8

CARD	ORDER		
1	1		
2	2		
3	3		
4	4		
5	5		
6		Next if required	
7			
N			
D			
T-1			
T-2			
C		Omit any cards that are inapplicable	
E			
S			
F			
P			
P-1 (or equivalent)		or Repeat for Each Lamina	Plate Definition Cards
P-2 (or equivalent)			
P-5		Repeat for elements in Repeat Substructure	
P-6			
B			
or B-1			All beam definition cards (Omit if no beams)
or B-2 (or equivalent)			
B-3 (or equivalent)			
B-8		Repeat for elements in Repeat Substructure	

6.4 Use of Tables

The program has a table input option to facilitate the repetitive nature of the input for the thicknesses, radii and material properties of the plate and beam elements. This option replaces the P-1, P-2 B-2 or B-3 cards. The first item of the P-1, P-2, B-2 and B-3 cards (lamina thickness or lamina radius) is specified on the T-1 card. All other items of the P-1, P-2, B-2 and B-3 cards are input on the T-2 card. These items are the material properties, E, ν, G or Q, for each layer. Each set of values on the T-2 card will be identified by a user table number. In a data set, it is permissible to use both input options for different elements, but the same input option must be used for all layers of any one element.

To use this table input, first input the proper parameter on columns 35 and 25 of the P and B cards, respectively. Then, on subsequent cards, one or more for each element, specify the table numbers for element material properties and the locations of the thicknesses or radii on the T-1 card. An example of the card is shown below.

```
(1,2,3,,,,1/  3,2,,5,6,7,6)
 thickness     material
 or radii      properties
```

The left and right parenthesis are used to initiate and terminate the data for one element. The / is used to separate the T-1 and T-2 entries. The numbers to the left of / corresponds to the n^{th} entries of the T-1 card. The numbers are input in the order of the layers and separated with commas. If a number is omitted between commas, the previous integer is used for that layer. The numbers of commas to the left and right of / must always be equal.

The data for the example above will be interpreted in the following manner.

Layer No.	n^{th} Item of T-1 Card	Table No. of T-2
1	1	3
2	2	2
3	3	2
4	3	5
5	3	6
6	3	7
7	1	6

7.0 OUTPUT

The printing of the input data is coordinated with the description of the input in Section 6.1. The items of output that are produced are as follows:

1. Header Page

2. Program Control Options
   Card 3

3. Problem Characteristics
   Card 4

4. Analysis Options
   Cards 5, 6 and 7

5. Nodal Data
   Card N

6. Substructure Definition Data
   Card D

7. Repeat Substructure Interrelationship Data
   Card C. Element I connects the start-repeat substructure and
   Element J connects the repeat-end substructure.

8. Equivalent Node Data
   Card E Node I is equivalent to Node J.

9. Table Data
   Cards T1 and T2

10. Element Data

<u>Plates</u>

Cards P, P-1 (or equivalent) or P-2 (or equivalent)

Each plate is accompanied by its A-, B- and D-matrices. The A-matrix represents the extensional stiffness of the plate element, while the B- and D-matrices are the coupling stiffness and bending stiffness, respectively. For thermal problems cards P-3 and P-4 will be printed and for input loads problems, P-5 and P-6. The A, B and D matrices are calculated relative to the element midplane.

<u>Beams</u>

Cards B, B-1, B-2 (or equivalent) or B-3 (or equivalent)

For thermal problems, either cards B-4 or B-5 and B-6 or B-7 will be printed. For input loads problems, B-8 card will be printed.

11. Plate Element Input Offsets

Card F

12. Plate Element Net Offsets

The net Zo offsets are measured from the midplane of the element to the point that is offset to.

13. Element Transformation Data

The plate element widths, the sines and cosines of the transformation angles (local to global) at the definition nodes and the element types are printed. The sign convention for the angles are shown in Figure 5.2 of Reference 2. The plate width for curved elements is the arc length between nodes.

14. Element Substructure Assignment Data

15. Field Length Data
The field length for the buckling calculation is exact, whereas the one for the eigenvector and thermal stresses calculation is an upper bound to the one needed.

16. Thermal Stresses and Displacements
The element thermal stresses and displacements are output with respect to the local coordinate systems. For every specified x-value, these stresses and displacements are printed at five equidistant local y-values of the plate element (LOADOP = 4). For LOADOP = 5, the N_{11} and N_{22} average loads are printed for each subelement when requested. (This is accomplished by specifying first and last print Harmonic. See Card 3, fields 8 and 9.)

17. Panel Upper Bound

18. Buckling Load or Critical Ratio Search History
The number of negative elements found on the diagonal of the panel matrix during the determinant calculation. The buckling determinant = $A.(2^B)$. There is a history printed for each wave number. This number of negative elements indicates the number of eigenvalues that is below the trial load. For LOADOP = 6 and 8 (critical ratio options), the ratios are printed instead of trial loads.

19. Element Loads
The inplane biaxial loads, N_{11} and N_{22}, and the biaxial strains, E_{11} and E_{22} for plate elements are printed here. For beam elements, the axial loads and strains are printed. The total loads, axial and transverse are also included. Sign convention used here is such that tension is (-) and compression is (+). For LOADOP = 6 or 8, there will be no element loads print.

20. Buckling Load Computation Summary

The critical wave number among those searched is identified. The buckling load for the first element of the panel is printed for each wave number. For LOADOP = 6 and 8, the critical ratios are summarized.

21. Eigenvector

For each iteration, the eigenvectors for every freedom of all nodes, with the exception of constrained or sprung nodes, are printed along with the normalizing factors. User should inspect these eigenvectors to check on convergence. These values are printed with respect to the global coordinates.

22. Relative Displacements

The element displacements are relative to the element local coordinate system.

8.0 SAMPLE PROBLEMS

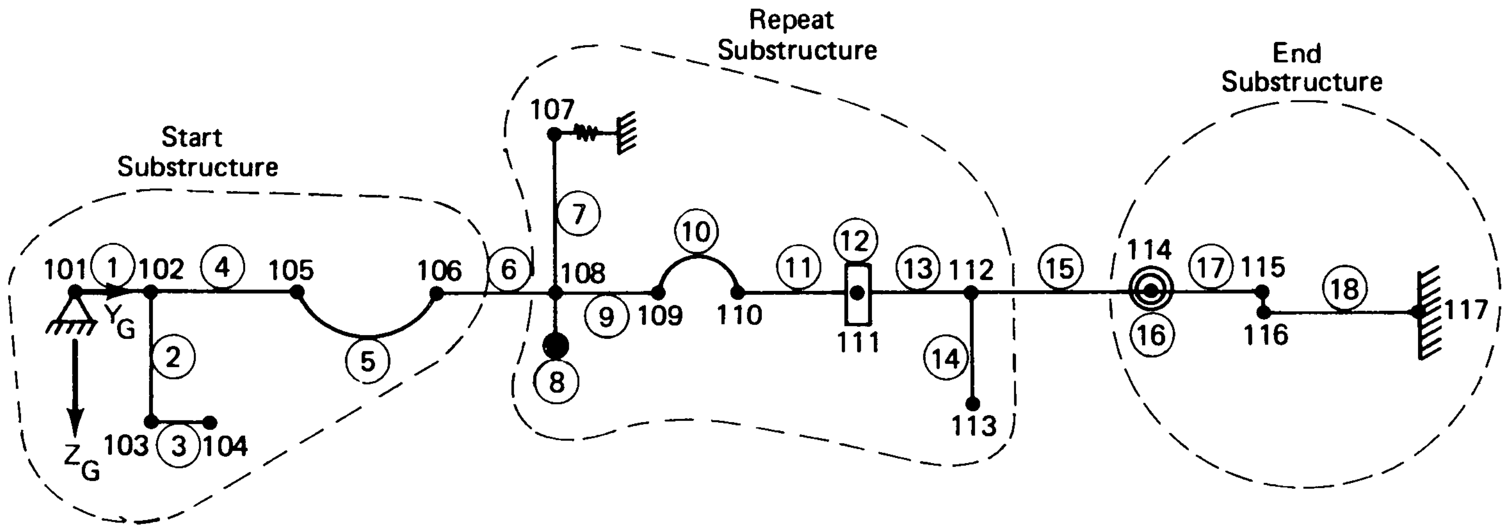
The input, output and accompanying sketches of four (4) sample problems are included in this section. The circled items on the figures and discussions are user element numbers and the uncircled integers are user node numbers.

8.1 Example 1: Potpourri Input Problem

The sample input for this problem is presented for this rather arbitrary structure, shown in Figure 8.1. This example is included here to illustrate many input features of BUCLASP3.

The total structure is assumed to comprise of two more repeat substructures than is shown in Figure 8.1. Node 101 is simply supported, node 117 clamped, node 107 sprung, and nodes 104 and 113 are free to deform. Plates 17 and 18 are separated by an offset of 1 inch. 16 is a three layered circular beam and 8 is a general beam element that is offset 2 inches from the midplanes of plate elements 6 and 9 .

Each of the plate elements 1 through 7 is subdivided into 3 subelements. Plate element 18 is subdivided into 5 subelements and each of the remaining elements is subdivided into 2 subelements. The critical load ratio option is used here and the plate subelement and beam input loads are specified.



5, 10 Curved Plate Elements

8 General Beam Element

12 Rectangular Beam Element

16 Circular Laminated Beam Element

Rest are Flat Plate Elements

Figure 8.1 Example No. 1 - Potpourri Input Problem

POTPOURRI INPUT PROBLEM

```
                    1                   2
  17     3    13    2    0                          500.        0.0        0.0
   8     2     1    1    0    1
N 101    1               0.0         0.0
N 102                    1.0         0.0
N 103                    1.0         2.0
N 104                    2.0         2.0
N 105                    5.0         0.0
N 106                   15.0         0.0
N 107    4              21.0        -0.7
N 108                   21.0         0.0
N 109                   30.0         0.0
N 110                   36.0         0.0
N 111                   47.0         0.0
N 112                   60.0         0.0
N 113    3              60.0        14.0
N 114                   66.0         0.0
N 115                   92.0         0.0
N 116                   92.0         1.0
N 117    2             110.0         1.0
D   5  101   106  107  113  114  117
S 107        1. E05
E 115  116   108  108  111  111  114  114
C 106  112
F   6        0.0       0.0       2.0       0.0
F   7        0.0       0.0       0.0       2.0
F   9        2.0       0.0       0.0       0.0
F  18           -1.0                 0.0
THICK           .02,.04,0.05 /
TABLE    3  30.E6,30.E6,.3,11.5E6/
TABLE    2   10.E6,9.8E6,.3,3.8E6 /
TABLE    1   15.E6,15.E6,.3, 5.8E6 /
P   1  101  102    1         1                                0    1    3
         .1     1.E7      1.E7       .3      3.E7
  -1.0     -1.2      -1.3
  -.3      -.25      -.23
P   2  102  103    1         3    1                           0    1    3
  (1,3,2/3,1,2)
-1.3       -1.2      -1.1
 -.25      -.27       -.3
P   3  103  104    1         1                                0    1    3
         .1     1.E7      1.E7       .3      3.E7
 -.5       0.2       0.5
 -.1        0.0       .1
P   4  102  105    1         1                                0    1    3
         .1     1.E7      1.E7       .3      3.E7
  -.9      -.7       -.3
  -.23      -.2      -.1
P   5  105  106    2    0    2                                0    1    3       -60.
         .1     1.E7      1.E7       .3      3.E7
```

```
.05         30.  E6              .3        12.  E6
 -.2       -.2       -.21
 -.05      -.03       -.06
P  6  106  108    1    1    2    1                     0    2    3
 (3,3/3,1)
 0.0      .05         .07
 -.2       -.1       -.3
 .1         .02          .03
 -.1        -.25           -.3
 0.1         .12          .13
 0.0      -0.05       -.02
P   7  107  108    1    1    1                         0    2    3
        .1      1.E7      1.E7        .3       3.E7
 -.1       -.15      -.15
 -.01      -.02        -.015
 -.1        -.11         -.12
 0.0        .01         .02
 -.2        -.3         -.5
 .01        .02         .03
P   9  108  109    1    1    1                         0    2
        .1      1.E7      1.E7        .3       3.E7
 -.27     -.29
-.1       -.1
 -.3        -.23
  -.05      -.05
 -.36       -.4
  0.0        0.0
P  10  109  110    2    0    1                         0    2          15.
        .1      1.E7      1.E7        .3       3.E7
 -.35     -.40
 -.2        -.3
 -.3        -.2
 -.3        -.2
 -.3        -.2
 -.3        -.2
P  11  110  111    1         1                         0    2
        .1      1.E7      1.E7        .3       3.E7
 -.4        -.6
 -.1        -.3
 -.5        -.5
 -.1          -.12
 -.5        -.5
 -.1          -.12
P  13  111  112    1         1                         0    2
        .1      1.E7      1.E7        .3       3.E7
 -.5       -.8
 -.25      .25
  -.66        -.65
  -.35       -.1
  -.66        -.65
 0.0         .1
P  14  112  113    1         1                         0    2
```

```
        .1      1.E7      1.E7        .3      3.E7
  -.8      -.9
 -.1      -.2
  -.85     -.60
  -.85     -.60
  0.0      0.0
  0.0      .1
P  15  112  114   1       2   1                    0   3
 (3,3/3,1)
  -.25       -.395
-.01      -.03
P  17  114  115   1       1                        0   3
        .1      1.E7      1.E7        .3      3.E7
  -.95     -1.35
  -.3     -.3
P  18  116  117   1   1   2                        0   3   5
        .1      1.E7      1.E7        .3      3.E7
        .3      1.E7      1.E7        .3      3.E7
  -1.0     -1.2     -1.3       -1.4     -1.5
  -.1     -.2      -.3       -.4      -.5
B   8  108   1            1   0   2              0.5
      1.E7     3.E6       .1        .3       .01      .15      2.0      0.0
  -10.0
 -8.0
  -7.0
B  12  111   2   1        1   0   2
        .2      1.E7      3.E7        .5
 -8.5
  -1.0
   -.3
B  16  114   3   3        1   0   3
       0.2      1.E7      3.E6
   0.25      15.  E7   3.5  E6
   0.3       30.  E6   12.  E6
  1.75
L
```

8.2 Example 2: Thermal Stress Analysis of a Stiffened Plate

The geometry and the temperature distribution of a stiffened plate is shown in Figure 8.2. In the cross sectional view, the node numbers are indicated as uncircled numbers and the element numbers are circled. The local axes of each plate element is shown with the subscripts indicating the element. The ends and sides of the panel are all simply supported. The properties of the plates and beams are shown below.

Plate Elements

Thickness = 0.25 in.

E = 1×10^7 lbs/in^2

ν = 0.3

α = 1×10^{-5} in/in/°F

Beam Elements

Area = 1.0 in^2

E = 1×10^7 lbs/in^2

G = 3.85×10^6 lbs/in^2

α = 1.0×10^{-5} in/in/°F

The temperature distribution of the panel along its width is parabolic with the peak temperature of 370°F at the middle of the panel and side temperatures of 10°F. As discussed previously, there is no variation of temperature in the X_G or x directions.

The coefficients of the polynomial, $T_{py} = a_y + b_y y + c_y y^2$, that describes the temperature distribution for each plate element are listed below.

Plate Element	a_y	b_y	c_y
1	210.0	13.333	-.27778
3	360.	3.333	-.27778
4	360.	-3.333	-.27778
6	210.	-13.333	-.27778

The beam elements, idealized with axial stiffnesses only, are input as General Beam elements. The required thermal axial load ($E\alpha\Delta T$) for the beam subjected to ΔT of 330°F is calculated from Equation (4.53) of Ref. 1 as 33000 lbs.

The harmonics of the Fourier series expansion for the constant temperature in the axial direction is truncated at 31.

If desired, only half of the panel along the width could have been analyzed due to symmetry.

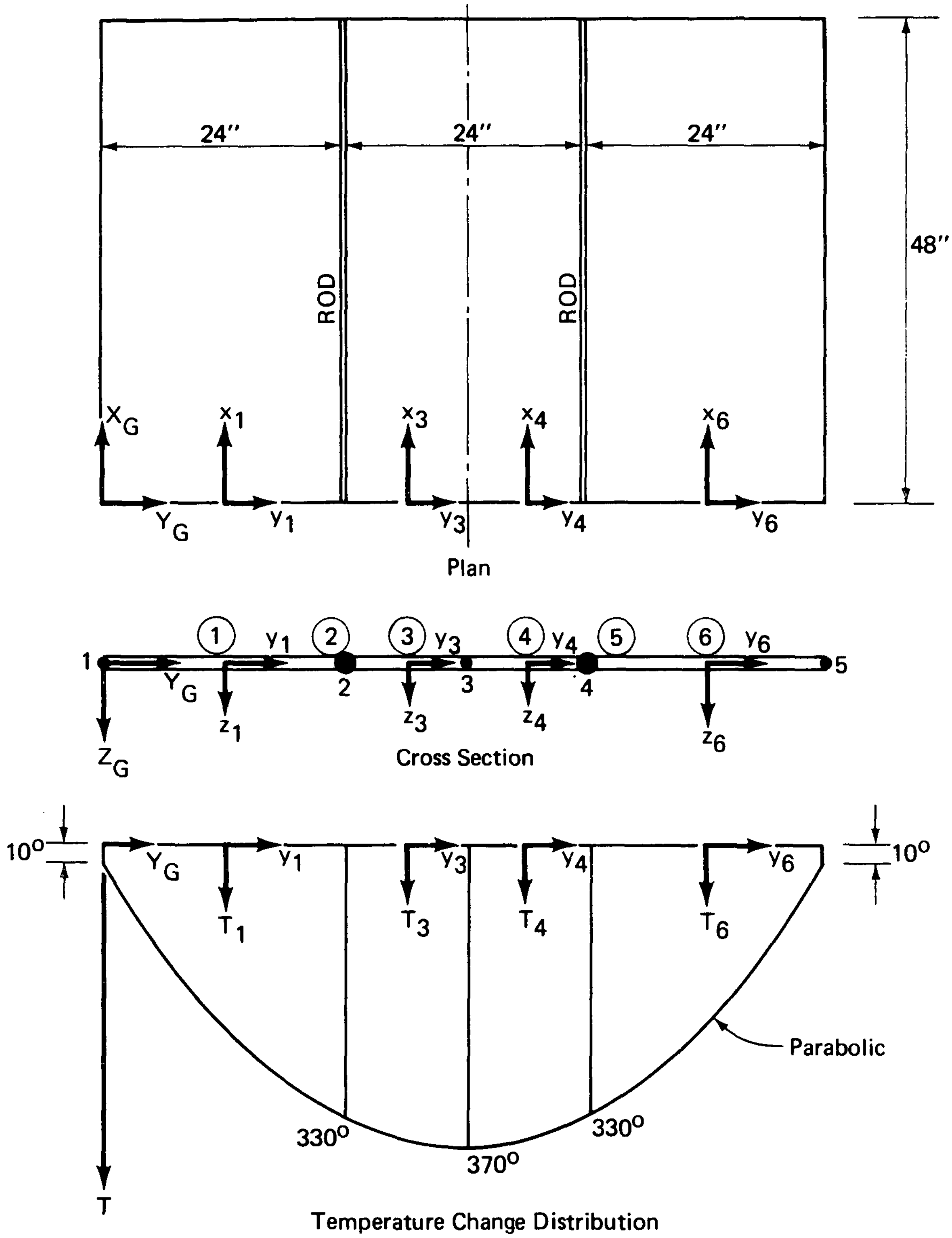


Figure 8.2 Stiffened Plate Example

```
     EXAMPLE NO.2  STIFFENED PLATE
    0    0    0    0    0    0    0
    0    0                   2    0   29   31   10
    5    2    4    0                        48.0                        31
    4    2    1    1
N   1    1             0.          0.
N   2    0            24.          0.
N   3    0            36.          0.
N   4    0            48.          0.
N   5    1            72.          0.
E   2    2    4    4
D   1    1    5
P   1    1    2    1    0    1        -0   -0   -0   -0    1    1
     .25       1.  E7    1.  E7     .3     3.8462E6
  1.0      210.     13.333333 -.2777777  1.0
   1.  E-5    1. E-5
P   3    2    3    1    0    1        -0   -0   -0   -0    1    1
     .25       1.  E7    1.  E7     .3     3.8462E6
  1.0      360.     3.3333333 -.2777777   1.0
   1.  E-5   1.  E-5
P   4    3    4    1    0    1        -0   -0    0   -0    1    1
     .25       1.  E7    1.  E7     .3     3.8462E6
  1.0      360.     -3.333333 -.2777777   1.0
   1.  E-5    1. E-5
P   6    4    5    1    0    1        -0   -0    0   -0    1    1
     .25       1.  E7    1.  E7     .3     3.8462E6
   1.0      210.     -13.33333 -.2777777  1.0
   1.  E-5    1. E-5
B   2    2    1   -0         0    1    1           1.0
    1. E7   3.85 E6    0.0       0.0
                     33000.
B   5    4    1   -0         0    1    1           1.0
    1. E7   3.85 E6    0.0       0.0
                     33000.
L
```

```
P R O G R A M   S 0 3 4 4 A / BUCLASP3                    NOV 01  72

THERMAL STRESS AND BUCKLING OF LAMINATED STIFFENED PANELS

LOADING               -- IN-PLANE BIAXIAL , THERMAL

BOUNDARY CONDITIONS -- (1) SIMPLY SUPPORTED ALONG EDGES PARALLEL TO THE TRANSVERSE AXIS

                       (2) ELASTICALLY RESTRAINED ALONG ANY EDGE PARALLEL TO THE LONGITUDINAL AXIS

TYPES OF ELEMENTS    -- (1) FLAT PLATE

                       (2) CURVED PLATE

                       (3) BEAM

    EXAMPLE NO.2  STIFFENED PLATE
```

THIS IS AN EDITTED EXAMPLE OF THE PROGRAM OUTPUT.

P R O G R A M   C O N T R O L   O P T I O N S

THERMAL STRESS ANALYSIS

P R O B L E M   C H A R A C T E R I S T I C S

NUMBER OF NODES	=	5
NUMBER OF FLAT PLATE ELEMENTS	=	4
NUMBER OF CURVED PLATE ELEMENTS	=	0
NUMBER OF BEAM ELEMENTS	=	2
PANEL LENGTH	=	48.000
MAXIMUM FOURIER HARMONIC	=	31

A N A L Y S I S   O P T I O N S

LOAD OPTION (LOADOP) = 4

WAVE NUMBER SEARCH OPTION (MOPT) = 2

INITIAL VALUE OF LONGITUDINAL WAVE NUMBER (MMI) = 1

FINAL VALUE OF LONGITUDINAL WAVE NUMBER (MMA) = 1

LOWER LIMIT FOR ROOT SEARCHING CRITERIA (NLW) = 0

UPPER LIMIT FOR ROOT SEARCHING CRITERIA (NUP) = 1

FLAT PLATE ELEMENT USER NUMBER 1 USER NODE I 1 USER NODE J 2

NUMBER OF BUCKLING SUBELEMENTS = 2

NUMBER OF RELATIVE DISPLACEMENT SUBDIVISIONS = 5

MATERIAL PROPERTY INPUT OPTION = -0

MATERIAL PROPERTY INPUT FORMAT OPTION = -0

THERMAL DATA INPUT OPTION = 0

LAYER	THICKNESS	EXX	EYY	NUXY	NUYX	G
1	2.500000E-01	1.000000E+07	1.000000E+07	3.000000E-01	3.000000E-01	3.846200E+06

A-MATRIX

2747252.747	824175.824	0.000
824175.824	2747252.747	0.000
0.000	0.000	961550.000

B-MATRIX

0.000	0.000	0.000
0.000	0.000	0.000
0.000	0.000	0.000

D-MATRIX

14308.608	4292.582	0.000
4292.582	14308.608	0.000
0.000	0.000	5008.073

T H E R M A L   P A R A M E T E R S

TX	TYA	TYB	TYC	TZA	TZB	TZC
1.00000E+00	2.10000E+02	1.33333E+01	-2.77778E-01	1.00000E+00	-0.	-0.

LAYER	ALPHX	ALPHY	TZ
1	1.00000E-05	0.	-0.

THERMAL
STRESSES AND DISPLACEMENTS

FOURIER TERM NUMBER = 29 START SUBSTRUCTURE NUMBER = 1 PLATE ELEMENT NUMBER = 1 Y = -12.0000

X	U	V	W	N11	N22	N12	M11	M22
0.0000	7.3519E-15	0.	0.	0.	0.	-8.3078E+03	0.	0.
2.6667	7.2363E-15	-1.0540E-02	0.	-2.3985E+02	9.6492E-11	-6.8467E+03	0.	0.
5.3333	6.8948E-15	-1.9221E-02	0.	-2.5860E+02	2.3493E-10	-5.7105E+03	0.	0.
8.0000	6.3217E-15	-2.6393E-02	0.	-2.6053E+02	3.7949E-10	-4.7225E+03	0.	0.
10.6667	5.5950E-15	-3.2233E-02	0.	-2.5383E+02	4.3119E-10	-3.8216E+03	0.	0.
13.3333	4.7207E-15	-3.6865E-02	0.	-2.4638E+02	5.4629E-10	-2.9780E+03	0.	0.
16.0000	3.6481E-15	-4.0381E-02	0.	-2.4389E+02	6.5387E-10	-2.1796E+03	0.	0.
18.6667	2.4923E-15	-4.2849E-02	0.	-2.4724E+02	7.1245E-10	-1.4226E+03	0.	0.
21.3333	1.2708E-15	-4.4314E-02	0.	-2.5272E+02	7.3342E-10	-7.0075E+02	0.	0.
24.0000	9.0658E-29	-4.4799E-02	0.	-2.5530E+02	7.4090E-10	-4.4614E-11	0.	0.

FOURIER TERM NUMBER = 29 START SUBSTRUCTURE NUMBER = 1 PLATE ELEMENT NUMBER = 1 Y = -6.0000

X	U	V	W	N11	N22	N12	M11	M22
0.0000	-2.4493E-02	0.	0.	0.	0.	-7.3659E+03	0.	0.
2.6667	-2.1028E-02	-9.5791E-03	0.	-3.8096E+02	-2.4965E+03	-6.4002E+03	0.	0.
5.3333	-1.7658E-02	-1.7716E-02	0.	-6.7223E+02	-2.4308E+03	-5.4090E+03	0.	0.
8.0000	-1.4631E-02	-2.4512E-02	0.	-8.9304E+02	-2.2271E+03	-4.4929E+03	0.	0.
10.6667	-1.1854E-02	-3.0072E-02	0.	-1.0613E+03	-1.9731E+03	-3.6423E+03	0.	0.
13.3333	-9.2576E-03	-3.4494E-02	0.	-1.1885E+03	-1.7503E+03	-2.8445E+03	0.	0.
16.0000	-6.8017E-03	-3.7854E-02	0.	-1.2818E+03	-1.6211E+03	-2.0898E+03	0.	0.
18.6667	-4.4603E-03	-4.0214E-02	0.	-1.3457E+03	-1.5925E+03	-1.3705E+03	0.	0.
21.3333	-2.2059E-03	-4.1614E-02	0.	-1.3830E+03	-1.6177E+03	-6.7786E+02	0.	0.
24.0000	-1.3035E-16	-4.2078E-02	0.	-1.3952E+03	-1.6353E+03	-4.0075E-11	0.	0.

FOURIER TERM NUMBER = 29 START SUBSTRUCTURE NUMBER = 1 PLATE ELEMENT NUMBER = 1 Y = 0.0000

X	U	V	W	N11	N22	N12	M11	M22
0.0000	-4.5992E-02	0.	0.	0.	0.	-6.2711E+03	0.	0.
2.6667	-3.9811E-02	-8.1756E-03	0.	-5.1343E+02	-4.5300E+03	-5.4919E+03	0.	0.
5.3333	-3.3633E-02	-1.5170E-02	0.	-9.4194E+02	-4.4993E+03	-4.6775E+03	0.	0.
8.0000	-2.7981E-02	-2.1042E-02	0.	-1.2938E+03	-4.1747E+03	-3.9106E+03	0.	0.
10.6667	-2.2736E-02	-2.5864E-02	0.	-1.5750E+03	-3.7371E+03	-3.1878E+03	0.	0.
13.3333	-1.7797E-02	-2.9710E-02	0.	-1.7924E+03	-3.3453E+03	-2.5015E+03	0.	0.
16.0000	-1.3101E-02	-3.2639E-02	0.	-1.9530E+03	-3.1153E+03	-1.8452E+03	0.	0.
18.6667	-8.6048E-03	-3.4699E-02	0.	-2.0631E+03	-3.0620E+03	-1.2139E+03	0.	0.
21.3333	-4.2601E-03	-3.5923E-02	0.	-2.1274E+03	-3.1042E+03	-6.0163E+02	0.	0.
24.0000	-2.5398E-16	-3.6329E-02	0.	-2.1486E+03	-3.1343E+03	-3.6226E-11	0.	0.

FOURIER TERM NUMBER = 29 START SUBSTRUCTURE NUMBER = 1 PLATE ELEMENT NUMBER = 1 Y = 6.0000

X	U	V	W	N11	N22	N12	M11	M22
0.0000	-6.3593E-02	0.	0.	0.	0.	-4.9202E+03	0.	0.
2.6667	-5.5297E-02	-6.4718E-03	0.	-6.2683E+02	-6.1566E+03	-4.3157E+03	0.	0.
5.3333	-4.6935E-02	-1.1970E-02	0.	-1.1648E+03	-6.1556E+03	-3.6910E+03	0.	0.
8.0000	-3.9228E-02	-1.6562E-02	0.	-1.5926E+03	-5.7384E+03	-3.1162E+03	0.	0.
10.6667	-3.2011E-02	-2.0338E-02	0.	-1.9208E+03	-5.1713E+03	-2.5690E+03	0.	0.
13.3333	-2.5149E-02	-2.3361E-02	0.	-2.1696E+03	-4.6655E+03	-2.0356E+03	0.	0.
16.0000	-1.8568E-02	-2.5675E-02	0.	-2.3532E+03	-4.3725E+03	-1.5127E+03	0.	0.
18.6667	-1.2221E-02	-2.7308E-02	0.	-2.4800E+03	-4.3111E+03	-1.0003E+03	0.	0.
21.3333	-6.0586E-03	-2.8280E-02	0.	-2.5546E+03	-4.3727E+03	-4.9724E+02	0.	0.
24.0000	-3.6543E-16	-2.8603E-02	0.	-2.5792E+03	-4.4146E+03	-3.0464E-11	0.	0.

FOURIER TERM NUMBER = 29 START SUBSTRUCTURE NUMBER = 1 PLATE ELEMENT NUMBER = 1 Y = 12.0000

X	U	V	W	N11	N22	N12	M11	M22
0.0000	-7.5061E-02	0.	0.	0.	0.	-1.9861E+03	0.	0.
2.6667	-6.6569E-02	-4.3467E-03	0.	-1.4582E+03	-7.0755E+03	-3.1428E+03	0.	0.
5.3333	-5.7272E-02	-8.1034E-03	0.	-1.7170E+03	-7.1889E+03	-2.8279E+03	0.	0.
8.0000	-4.8287E-02	-1.1293E-02	0.	-1.9501E+03	-6.8085E+03	-2.3879E+03	0.	0.
10.6667	-3.9631E-02	-1.3940E-02	0.	-2.1265E+03	-6.2271E+03	-1.9507E+03	0.	0.
13.3333	-3.1264E-02	-1.6070E-02	0.	-2.2736E+03	-5.6895E+03	-1.5489E+03	0.	0.
16.0000	-2.3156E-02	-1.7702E-02	0.	-2.4229E+03	-5.3751E+03	-1.1739E+03	0.	0.
18.6667	-1.5279E-02	-1.8855E-02	0.	-2.5746E+03	-5.3116E+03	-8.0023E+02	0.	0.
21.3333	-7.5857E-03	-1.9542E-02	0.	-2.6949E+03	-5.3821E+03	-4.0868E+02	0.	0.
24.0000	-4.6441E-16	-1.9770E-02	0.	-2.7413E+03	-5.4292E+03	-7.3702E-12	0.	0.

FOURIER TERM NUMBER = 29 START SUBSTRUCTURE NUMBER = 1 BEAM ELEMENT NUMBER = 2

X	MZ	MY	TORQUE	AXIAL LOAD
0.0000	0.	0.	0.	0.
2.6667	0.	0.	0.	2.6578E+03
5.3333	0.	0.	0.	1.7589E+03
8.0000	0.	0.	0.	3.6974E+02
10.6667	0.	0.	0.	-1.0336E+03
13.3333	0.	0.	0.	-2.2670E+03
16.0000	0.	0.	0.	-3.2414E+03
18.6667	0.	0.	0.	-3.9243E+03
21.3333	0.	0.	0.	-4.3209E+03
24.0000	0.	0.	0.	-4.4500E+03

FOURIER TERM NUMBER = 29 START SUBSTRUCTURE NUMBER = 1 PLATE ELEMENT NUMBER = 3 Y = -6.0000

X	U	V	W	N11	N22	N12	M11	M22
0.0000	-7.5061E-02	0.	0.	0.	0.	-4.6609E+03	0.	0.
2.6667	-6.6569E-02	-4.3467E-03	0.	-1.4582E+03	-7.0755E+03	-2.7229E+03	0.	0.
5.3333	-5.7272E-02	-8.1034E-03	0.	-1.7170E+03	-7.1889E+03	-2.2130E+03	0.	0.
8.0000	-4.8267E-02	-1.1293E-02	0.	-1.9501E+03	-6.6085E+03	-1.8612E+03	0.	0.
10.6667	-3.9631E-02	-1.3940E-02	0.	-2.1265E+03	-6.2271E+03	-1.5356E+03	0.	0.
13.3333	-3.1264E-02	-1.6070E-02	0.	-2.2736E+03	-5.6895E+03	-1.1996E+03	0.	0.
16.0000	-2.3156E-02	-1.7702E-02	0.	-2.4229E+03	-5.3751E+03	-8.6004E+02	0.	0.
18.6667	-1.5279E-02	-1.8855E-02	0.	-2.5746E+03	-5.3116E+03	-5.4065E+02	0.	0.
21.3333	-7.5867E-03	-1.9542E-02	0.	-2.6949E+03	-5.3821E+03	-2.5669E+02	0.	0.
24.0000	-4.6441E-16	-1.9770E-02	0.	-2.7413E+03	-5.4292E+03	-3.3551E-11	0.	0.

FOURIER TERM NUMBER = 29 START SUBSTRUCTURE NUMBER = 1 PLATE ELEMENT NUMBER = 3 Y = -3.0000

X	U	V	W	N11	N22	N12	M11	M22
0.0000	-8.0982E-02	0.	0.	0.	0.	-2.5117E+03	0.	0.
2.6667	-7.0695E-02	-3.1129E-03	0.	-8.3005E+02	-7.7232E+03	-2.2462E+03	0.	0.
5.3333	-6.0328E-02	-5.9842E-03	0.	-1.4397E+03	-7.7285E+03	-1.8722E+03	0.	0.
8.0000	-5.0665E-02	-8.4718E-03	0.	-1.8658E+03	-7.2590E+03	-1.5190E+03	0.	0.
10.6667	-4.1493E-02	-1.0541E-02	0.	-2.1952E+03	-6.6012E+03	-1.2101E+03	0.	0.
13.3333	-3.2684E-02	-1.2201E-02	0.	-2.4563E+03	-6.0047E+03	-9.3433E+02	0.	0.
16.0000	-2.4176E-02	-1.3471E-02	0.	-2.6570E+03	-5.6600E+03	-6.8155E+02	0.	0.
18.6667	-1.5933E-02	-1.4359E-02	0.	-2.7997E+03	-5.5944E+03	-4.4512E+02	0.	0.
21.3333	-7.9050E-03	-1.4898E-02	0.	-2.8850E+03	-5.6763E+03	-2.1971E+02	0.	0.
24.0000	-4.8335E-16	-1.5075E-02	0.	-2.9134E+03	-5.7300E+03	-1.1500E-11	0.	0.

8.3 Example 3: Thermal Buckling of a Cylinder Heated Along an Axial Strip

Figure 8.3 shows the cylinder properties and the idealized structure of this sample problem which also appears in Ref. 3. The problem here is to compute the critical temperature ratio, the value of T_0 when buckling occurs.

The circled numbers indicate element numbers and the node numbers are uncircled. Only half of the cylinder is considered with appropriate symmetry conditions imposed. As the figure indicates, three groups of elements are used, all elements equally spaced within its group. Every element is divided into 5 subelements.

The initial temperature distribution in the hoop direction is approximated by seven different parabolic equations for elements 1 to 7 and no temperature change for the rest of the elements.

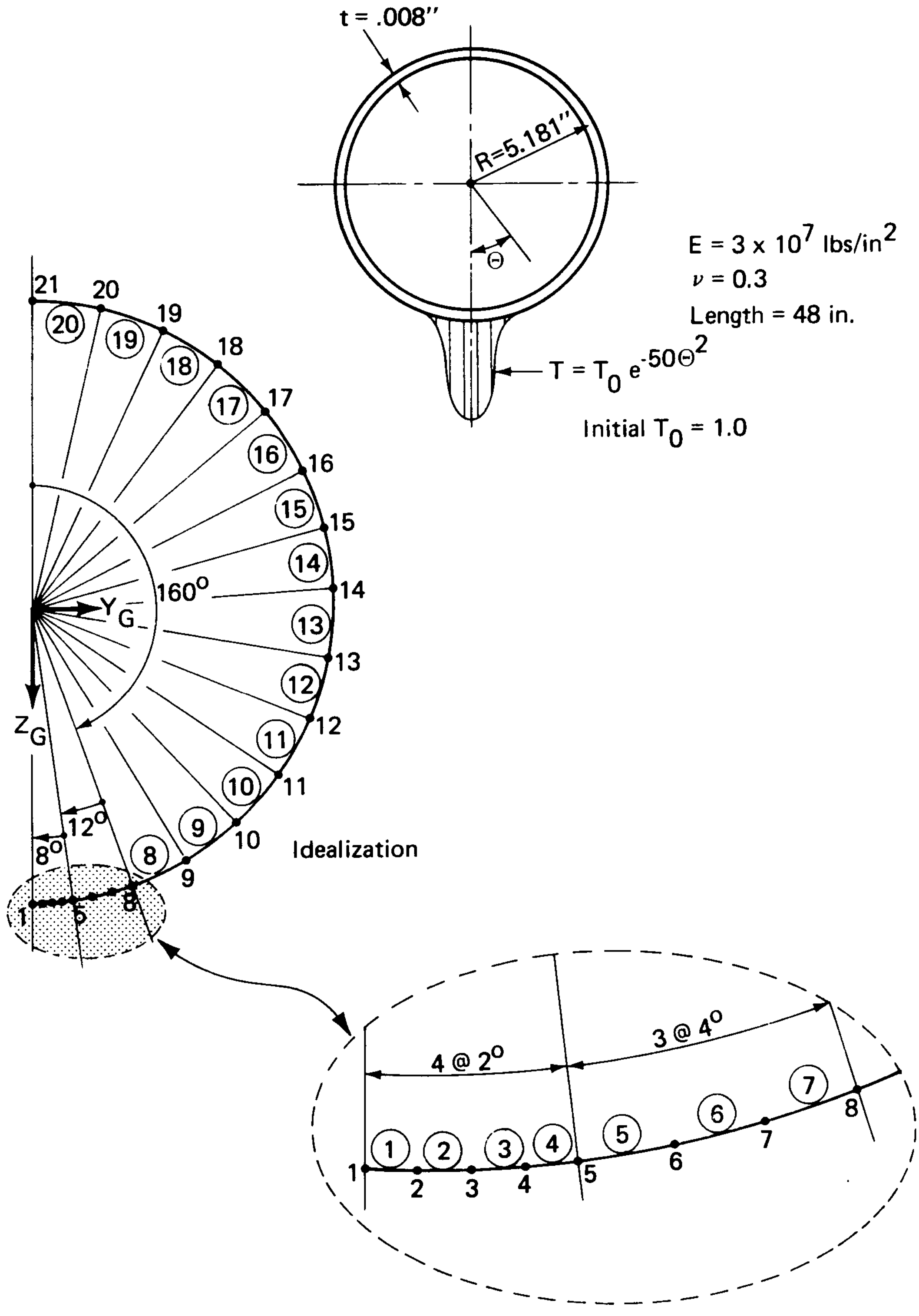


Figure 8.3 Strip Heated Cylinder

```
   EXAMPLE NO.3  STRIP HEATED CYLINDER
    0    0    0    0    0    0    0
    0    1    1              2    5   49   51    5
   21    0    0   20                   48.0                          51
    6    2  139  139
N   1    4             0.0       5.181
N   2    0            .180814295.1778439
N   3    0            .361408295.1683793
N   4    0            .541561975.1526179
N   5    0            .721055845.1305789
N   6    0           1.0771905 5.0677827
N   7    0           1.4280771 4.9802968
N   8    0           1.7720064 4.8685475
N   9    0            2.769057  4.37893
N  10    0            3.638845  3.68803
N  11    0            4.34136   2.827606
N  12    0            4.844319  1.837208
N  13    0            5.124604  0.762361
N  14    0            5.169331 -0.347529
N  15    0            4.976444 -1.441445
N  16    0            4.55481  -2.469103
N  17    0            3.923809 -3.383265
N  18    0            3.112446 -4.141913
N  19    0            2.158016 -4.710173
N  20    0            1.104390 -5.061925
N  21    4             0.0      -5.181
D   2    2   10              11   20
S   1                  1. E20    1. E20
S  21                 1.   E20 1.   E20
P   1    1    2    2    0    1       -0   -0    0   -0    1    1       -5.181
   .008      3. E7    3.  E7      .3      11.53E6
   1.0   .9848845  -.3258147 -1.765601     1.0
  6.  E-6   6.  E-6
P   2    2    3    2    0    1       -0   -0    0   -0    1    1       -5.181
   .008      3. E7    3.  E7      .3      11.53E6
   1.0   .8719024  -.8690455 -1.172957     1.0
  6.  E-6   6.  E-6
P   3    3    4    2    0    1       -0   -0    0   -0    1    1       -5.181
   .008      3. E7    3.  E7      .3      11.53E6
   1.0   .6833338  -1.137967 -.3066789     1.0
  6.  E-6   6.  E-6
P   4    4    5    2    0    1       -0   -0    0   -0    1    1       -5.181
   .008      3. E7    3.  E7      .3      11.53E6
   1.0   .4741115  -1.109465  .426744      1.0
  6.  E-6   6.  E-6
P   5    5    6    2    0    1       -0   -0    0   -0    1    1       -5.181
   .008      3. E7    3.  E7      .3      11.53E6
   1.0   .2180377  -.7345457  .8064855     1.0
  6.  E-6   6.  E-6
P   6    6    7    2    0    1       -0   -0    0   -0    1    1       -5.181
   .008      3. E7    3.  E7      .3      11.53E6
   1.0   .05052683 -.2524012  .4702425     1.0
```

```
    6.  E-6    6.  E-6
P   7    7    8    2    0    1        -0    -0    0    -0    1    1        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
    1.0    .007191883-.04976467 .1243829     1.0
    6.  E-6    6.  E-6
P   8    8    9    2    0    1        -0    -0    0    -0    1    1        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
    1.0     1.0
    6.  E-6    6.  E-6
P   9    9   10    2    0    1        -0    -0    0    -0    1    1        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
    1.0     1.0
    6.  E-6    6.  E-6
P  10   10   11    2    0    1        -0    -0    0    -0    1    3        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
    1.0     1.0
    6.  E-6    6.  E-6
P  11   11   12    2    0    1        -0    -0    0    -0    1    3        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
   1.0        1.0
    6.  E-6    6.  E-6
P  12   12   13    2    0    1        -0    -0    0    -0    1    3        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
   1.0        1.0
    6.  E-6    6.  E-6
P  13   13   14    2    0    1        -0    -0    0    -0    1    3        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
   1.0        1.0
    6.  E-6    6.  E-6
P  14   14   15    2    0    1        -0    -0    0    -0    1    3        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
   1.0        1.0
    6.  E-6    6.  E-6
P  15   15   16    2    0    1        -0    -0    0    -0    1    3        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
   1.0        1.0
    6.  E-6    6.  E-6
P  16   16   17    2    0    1        -0    -0    0    -0    1    3        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
   1.0        1.0
    6.  E-6    6.  E-6
P  17   17   18    2    0    1        -0    -0    0    -0    1    3        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
   1.0        1.0
    6.  E-6    6.  E-6
P  18   18   19    2    0    1        -0    -0    0    -0    1    3        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
   1.0        1.0
    6.  E-6    6.  E-6
P  19   19   20    2    0    1        -0    -0    0    -0    1    3        -5.181
    .008       3. E7    3.  E7     .3       11.53E6
   1.0        1.0
```

```
   6.  E-6   6.  E-6
P  20   20   21    2    0    1        -0   -0    0   -0    1    3        -5.181
    .008        3. E7    3.  E7     .3       11.53E6
   1.0        1.0
   6.  E-6   6.  E-6
L
```

P R O G R A M   S 0 3 4 4 A / BUCLASP3   NOV 01 72

THERMAL STRESS AND BUCKLING OF LAMINATED STIFFENED PANELS

LOADING -- IN-PLANE BIAXIAL , THERMAL

BOUNDARY CONDITIONS -- (1) SIMPLY SUPPORTED ALONG EDGES PARALLEL TO THE TRANSVERSE AXIS

(2) ELASTICALLY RESTRAINED ALONG ANY EDGE PARALLEL TO THE LONGITUDINAL AXIS

TYPES OF ELEMENTS -- (1) FLAT PLATE

(2) CURVED PLATE

(3) BEAM

EXAMPLE NO.3 STRIP HEATED CYLINDER

THIS IS AN EDITTED EXAMPLE OF THE PROGRAM OUTPUT.

N O D A L   D A T A

NODE	COORDINATES Y	COORDINATES Z	BOUNDARY CONDITIONS CODE	SPRING STIFFNESSES K (W)	K (THETA)	K (V)	K (U)
1	0.00000	5.18100	4	-0.	1.00000000E+20	1.00000000E+20	-0.
2	.18081	5.17734	0				
3	.36141	5.16838	0				
4	.54156	5.15262	0				
5	.72106	5.13058	0				
6	1.07719	5.06778	0				
7	1.42808	4.98030	0				
8	1.77201	4.86855	0				
9	2.76907	4.37893	0				
10	3.63885	3.68803	0				
11	4.34136	2.82761	0				
12	4.84432	1.83721	0				
13	5.12460	.76236	0				
14	5.16933	-.34753	0				
15	4.97644	-1.44145	0				
16	4.55481	-2.46910	0				
17	3.92381	-3.38326	0				
18	3.11245	-4.14191	0				
19	2.15802	-4.71017	0				
20	1.10439	-5.06193	0				
21	0.00000	-5.18100	4	-0.	1.00000000E+20	1.00000000E+20	-0.

S U B S T R U C T U R E   D E F I N I T I O N   D A T A

NUMBER OF SUBSTRUCTURES = 2

SUBSTRUCTURE	FIRST NODE	LAST NODE
START	2	10
END	11	20

ELEMENT TRANSFORMATION DATA

ELEM. NO.	WIDTH	TRANSFORMATION SIN(I)	COS(I)	SIN(J)	COS(J)	EL.TYPE
1	.18085	.00000	1.00000	-.03490	.99939	CRVD PLATE
2	.18085	-.03490	.99939	-.06976	.99756	CRVD PLATE
3	.18085	-.06976	.99756	-.10453	.99452	CRVD PLATE
4	.18085	-.10453	.99452	-.13917	.99027	CRVD PLATE
5	.36170	-.13917	.99027	-.20791	.97815	CRVD PLATE
6	.36170	-.20791	.97815	-.27564	.96126	CRVD PLATE
7	.36170	-.27564	.96126	-.34202	.93969	CRVD PLATE
8	1.11293	-.34202	.93969	-.53447	.84519	CRVD PLATE
9	1.11293	-.53447	.84519	-.70234	.71184	CRVD PLATE
10	1.11293	-.70234	.71184	-.83794	.54576	CRVD PLATE
11	1.11293	-.83794	.54576	-.93502	.35460	CRVD PLATE
12	1.11293	-.93502	.35460	-.98911	.14715	CRVD PLATE
13	1.11293	-.98911	.14715	-.99775	-.06708	CRVD PLATE
14	1.11293	-.99775	-.06708	-.96052	-.27822	CRVD PLATE
15	1.11293	-.96052	-.27822	-.87914	-.47657	CRVD PLATE
16	1.11293	-.87914	-.47657	-.75735	-.65301	CRVD PLATE
17	1.11293	-.75735	-.65301	-.60074	-.79944	CRVD PLATE
18	1.11293	-.60074	-.79944	-.41652	-.90912	CRVD PLATE
19	1.11293	-.41652	-.90912	-.21316	-.97702	CRVD PLATE
20	1.11293	-.21316	-.97702	.00000	-1.00000	CRVD PLATE

ELEMENT SUBSTRUCTURE ASSIGNMENT DATA

NUMBER	BLOCK
1	START
2	START
3	START
4	START
5	START
6	START

```
  5       -.00297      -.00003

AVERAGED STRESSES FOR ELEMENT  11   SUBSTRUCTURE END
  1       -.00290      -.00003    2      -.00281      -.00003    3      -.00274      -.00003    4      -.00269      -.00004
  5       -.00265      -.00004

 STIFFNESS MATRIX BANDWIDTH =    6


AVERAGED STRESSES FOR ELEMENT   1   SUBSTRUCTURE START
  1       -.89084      -.00394    2      -.88424      -.00392    3      -.87145      -.00387    4      -.85244      -.00379
  5       -.82722      -.00370

AVERAGED STRESSES FOR ELEMENT   2   SUBSTRUCTURE START
  1       -.79578      -.00358    2      -.75976      -.00345    3      -.71975      -.00329    4      -.67566      -.00312
  5       -.62754      -.00293

AVERAGED STRESSES FOR ELEMENT   3   SUBSTRUCTURE START
  1       -.57573      -.00274    2      -.52264      -.00253    3      -.46871      -.00232    4      -.41391      -.00210
  5       -.35822      -.00188

AVERAGED STRESSES FOR ELEMENT   4   SUBSTRUCTURE START
  1       -.30215      -.00165    2      -.24774      -.00143    3      -.19514      -.00122    4      -.14433      -.00101
  5       -.09529      -.00080

AVERAGED STRESSES FOR ELEMENT   5   SUBSTRUCTURE START
  1       -.02604      -.00051    2       .05529      -.00016    3       .12413       .00015    4       .18059       .00041
  5        .22476       .00062

AVERAGED STRESSES FOR ELEMENT   6   SUBSTRUCTURE START
  1        .25630       .00078    2       .27907       .00091    3       .29480       .00099    4       .30355       .00105
  5        .30537       .00108

AVERAGED STRESSES FOR ELEMENT   7   SUBSTRUCTURE START
  1        .30158       .00109    2       .29609       .00109    3       .28893       .00108    4       .28010       .00105
  5        .26963       .00104

AVERAGED STRESSES FOR ELEMENT   8   SUBSTRUCTURE START
  1        .24791       .00098    2       .21142       .00090    3       .17729       .00083    4       .14560       .00076
  5        .11639       .00069

AVERAGED STRESSES FOR ELEMENT   9   SUBSTRUCTURE START
  1        .08969       .00052    2       .06553       .00055    3       .04390       .00047    4       .02480       .00040
  5        .00819       .00032

AVERAGED STRESSES FOR ELEMENT  10   SUBSTRUCTURE START
  1       -.00599       .00025    2      -.01782       .00018    3      -.02738       .00011    4      -.03481       .00005
  5       -.04022      -.00001

AVERAGED STRESSES FOR ELEMENT   1   SUBSTRUCTURE END
  1       -.00599       .00025    2      -.01782       .00018    3      -.02738       .00011    4      -.03481       .00005
  5       -.04022      -.00001

AVERAGED STRESSES FOR ELEMENT   2   SUBSTRUCTURE END
  1       -.04379      -.00006    2      -.04367      -.00011    3      -.04604      -.00014    4      -.04509      -.00018
  5       -.04301      -.00020

AVERAGED STRESSES FOR ELEMENT   3   SUBSTRUCTURE END
  1       -.04000      -.00022    2      -.03625      -.00023    3      -.03195      -.00023    4      -.02727      -.00023
  5       -.02239      -.00022

AVERAGED STRESSES FOR ELEMENT   4   SUBSTRUCTURE END
```

```
  1       -.01745       -.00021    2       -.01262       -.00019    3      -.00799       -.00017    4      -.00368       -.00015
  5        .00023       -.00012

AVERAGED STRESSES FOR ELEMENT   5   SUBSTRUCTURE END
  1        .00368       -.00010    2        .00562       -.00007    3       .00904       -.00005    4       .01093       -.00002
  5        .01228        .00000

AVERAGED STRESSES FOR ELEMENT   6   SUBSTRUCTURE END
  1        .01314        .00002    2        .01352        .00004    3       .01349        .00005    4       .01309        .00006
  5        .01237        .00007

AVERAGED STRESSES FOR ELEMENT   7   SUBSTRUCTURE END
  1        .01141        .00008    2        .01025        .00008    3       .00895        .00008    4       .00759        .00008
  5        .00620        .00008

AVERAGED STRESSES FOR ELEMENT   8   SUBSTRUCTURE END
  1        .00482        .00007    2        .00350        .00006    3       .00227        .00006    4       .00115        .00005
  5        .00016        .00004

AVERAGED STRESSES FOR ELEMENT   9   SUBSTRUCTURE END
  1       -.00069        .00003    2       -.00140        .00002    3      -.00197        .00001    4      -.00240        .00001
  5       -.00271       -.00000

AVERAGED STRESSES FOR ELEMENT  10   SUBSTRUCTURE END
  1       -.00291       -.00001    2       -.00301       -.00001    3      -.00305       -.00002    4      -.00303       -.00002
  5       -.00297       -.00003

AVERAGED STRESSES FOR ELEMENT  11   SUBSTRUCTURE END
  1       -.00290       -.00003    2       -.00281       -.00003    3      -.00274       -.00003    4      -.00269       -.00004
  5       -.00256       -.00004
```

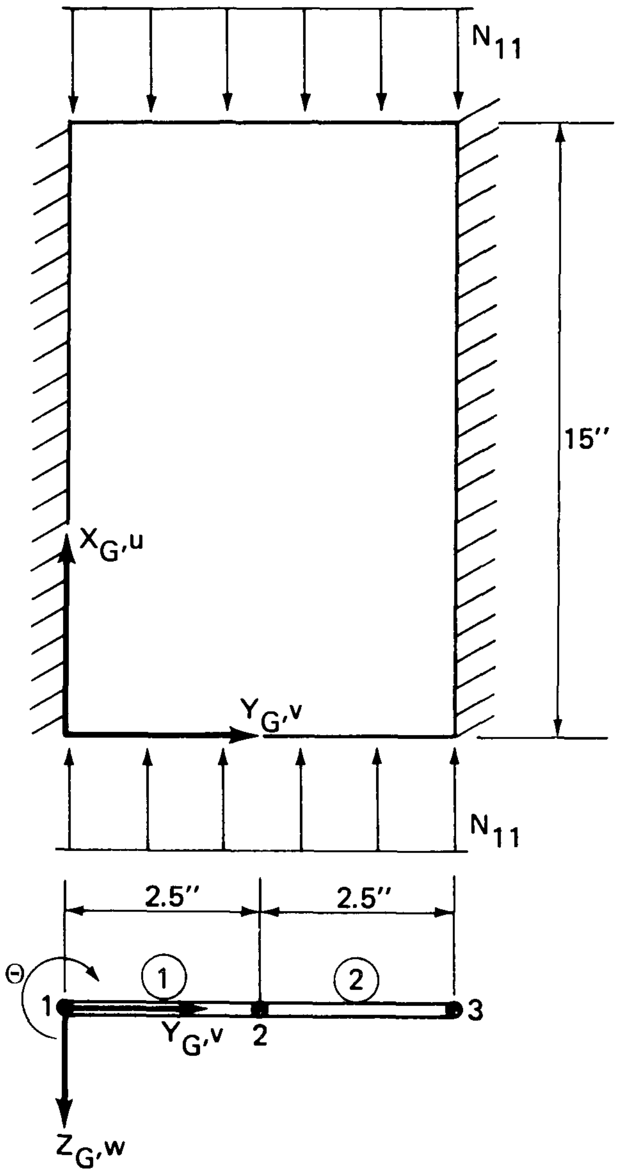
```
*******************************
*                             *
*    MODE   IS   M =  130     *
*                             *
*                             *
*******************************
```

EXAMPLE NO.3 STRIP HEATED CYLINDER

VARIABLE RATIO ON FIRST PLATE ELEMENT	NUMBER OF NEG. ON DIAGONAL	BUCKLING DETERMINANT (A*(2**B)) A	B	COMMENTS
160.0000000	0	.41021	1156	
240.0000000	0	.14562	1156	
280.0000000	0	.30644	1152	
300.0000000	1	-.63932	1152	
290.0000000	1	-.17334	1152	
285.0000000	0	.06494	1152	
287.5000000	1	-.87389	1148	
286.2500000	0	.08090	1148	
286.8750000	1	-.39691	1148	
286.5625000	1	-.15811	1148	
286.4062500	1	-.61808	1144	
286.3281250	0	.33805	1144	
286.3671875	1	-.14004	1144	
286.3476562	0	.09900	1144	
286.3574219	1	-.32838	1140	
286.3525391	0	.62778	1140	
286.3549805	0	.14970	1140	
286.3562012	1	-.08934	1140	
286.3555908	0	.48292	1136	
286.3558960	1	-.47324	1136	
286.3557434	0	.07745	1132	
286.3558197	1	-.23420	1136	
286.3557816	1	-.11468	1136	
286.3557625	1	-.87872	1132	
286.3557529	1	-.40063	1132	
286.3557482	1	-.16159	1132	
286.3557458	1	-.67321	1128	
286.3557446	0	.28297	1128	
286.3557452	1	-.19512	1128	

8.4 Example 4: Mechanical Buckling of a Heated Plate

The pertinent data for this example is shown in Figure 8.4. The critical N_{11} mechanical load is computed for this plate that is heated 35°F. Each plate element is divided into 5 subelements.



$E = 1 \times 10^7$ lbs/in^2

$\nu = 0.3$

$t = .1$ in.

$\alpha = 1.0 \times 10^{-5}$ in/in/^{o}F

$T = 35^{o}$ F (uniform)

Boundary Conditions Along $Y_G = 0, 5.0$

$w = 0$

$\Theta = 0$

$v = 0$

$u \neq 0$

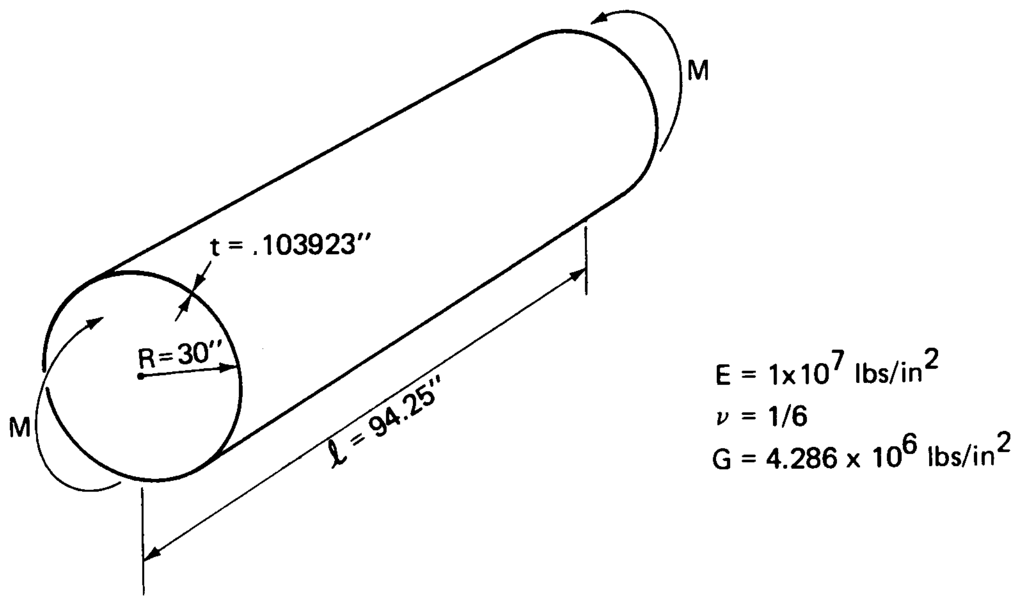
Figure 8.4 Clamped Rectangular Plate

```
    EXAMPLE NO.4  MECHANICAL BUCKLING OF A HEATED PLATE
    0    0    0    0    0    0    0
    0    1                   2    2    29   31   0
    3    0    2    0                        15.0                              31
    5    2    4    4
N   1    4              0.0       0.0
N   2    0              2.5       0.0
N   3    4              5.0       0.0
C   1    1    3
S   1         1.  E50  1.  E50  1.   E50
S   3         1.  E50  1.  E50  1.   E50
P   1    1    2    1    0    1        -0   -0   0   -0   1   1
     .1        1.  E7   1.  E7     .3      3.85 E6
    1.0       35.0                         1.0
    1. E-5    1.  E-5
P   2    2    3    1    0    1        -0   -0   0   -0   1   1
     .1        1.  E7   1.  E7     .3      3.85 E6
    1.0       35.0                         1.0
    1. E-5    1.  E-5
L
```

8.5 Example 5: Buckling of a Cylinder Under Bending

The relevant information concerning this example is shown in Figure 8.5. The cylinder is idealized as a half cylinder because only symmetrical buckling patterns about the diameter are considered. Each element is divided into 5 subelements. The problem here is to calculate the critical load ratio which by definition is the ratio of the critical bending moment to the initially applied bending moment. The initial bending moment is approximated by applying different axial loads to each subelement as shown in Figure 8.5. These axial loads, N_{11}, must be a constant value for each subelement.

The initial bending moment is chosen such that the crown N_{11} = 1787 lbs./in.. Tensile loads are input as positive values and compressive loads as negative values.



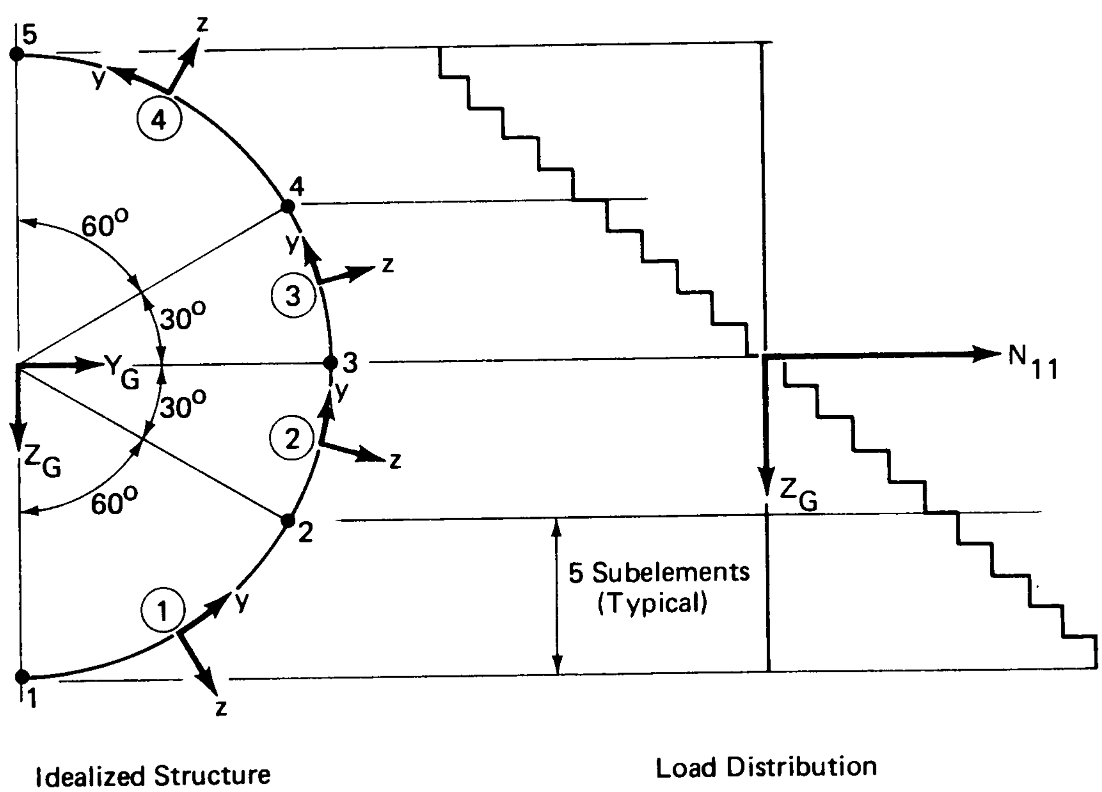


Figure 8.5 Cylinder Under Bending

```
    EXAMPLE NO.5  BUCKLING OF A CYLINDER UNDER BENDING
    0    0    0    0    0    0    0
    0    1                   0    5    0    0    0
    5    0    0    4                        94.25                          0
    8    2   16   19
N   1    4            0.0        30.0
N   2    0         25.980762  15.0
N   3    0         30.          0.0
N   4    0        25.980762  -15.0
N   5    4            0.0       -30.
D   1    1    5
S   1                  1.    E20   1.  E20
S   5                  1.    E20   1.  E20
P   1    1    2    2    0    1        -0   -0    0   -0    0    1       -30.0
  .103923     1.  E7    1.  E7     .16667    4.286E6
 1773.964 1696.4334 1544.7604 1325.5739 1048.4535

P   2    2    3    2    0    1        -0   -0    0   -0    0    1       -30.0
  .103923     1.  E7    1.  E7     .16667    4.286E6
 810.9104 640.1110  462.2983  279.4207  93.4816

P   3    3    4    2    0    1        -0   -0    0   -0    0    1       -30.0
  .103923     1.  E7    1.  E7     .16667    4.286E6
-93.4816  -279.4207 -462.2983 -640.1110 -810.9104

P   4    4    5    2    0    1        -0   -0    0   -0    0    1       -30.0
  .103923     1.  E7    1.  E7     .16667    4.286E6
-1048.4535-1325.5739-1544.7604-1696.4334-1773.964

L
```

8.6 Example 6: Buckling of a Plate Subjected to Inplane Bending and Compression

The data for this example problem is shown in Figure 8.5. The plate is simply supported along all exterior edges. For this problem, M is applied initially and then the N_{11} critical load, corresponding to P of the figure, is computed. All elements are divided into 5 subelements and the N_{11} loads simulating the initial bending moment, M, are applied to each subelement as shown. The magnitude of the initial bending moment is such that it results in a N_{11} load of 46.885 lbs./in. at the sides of the plate.

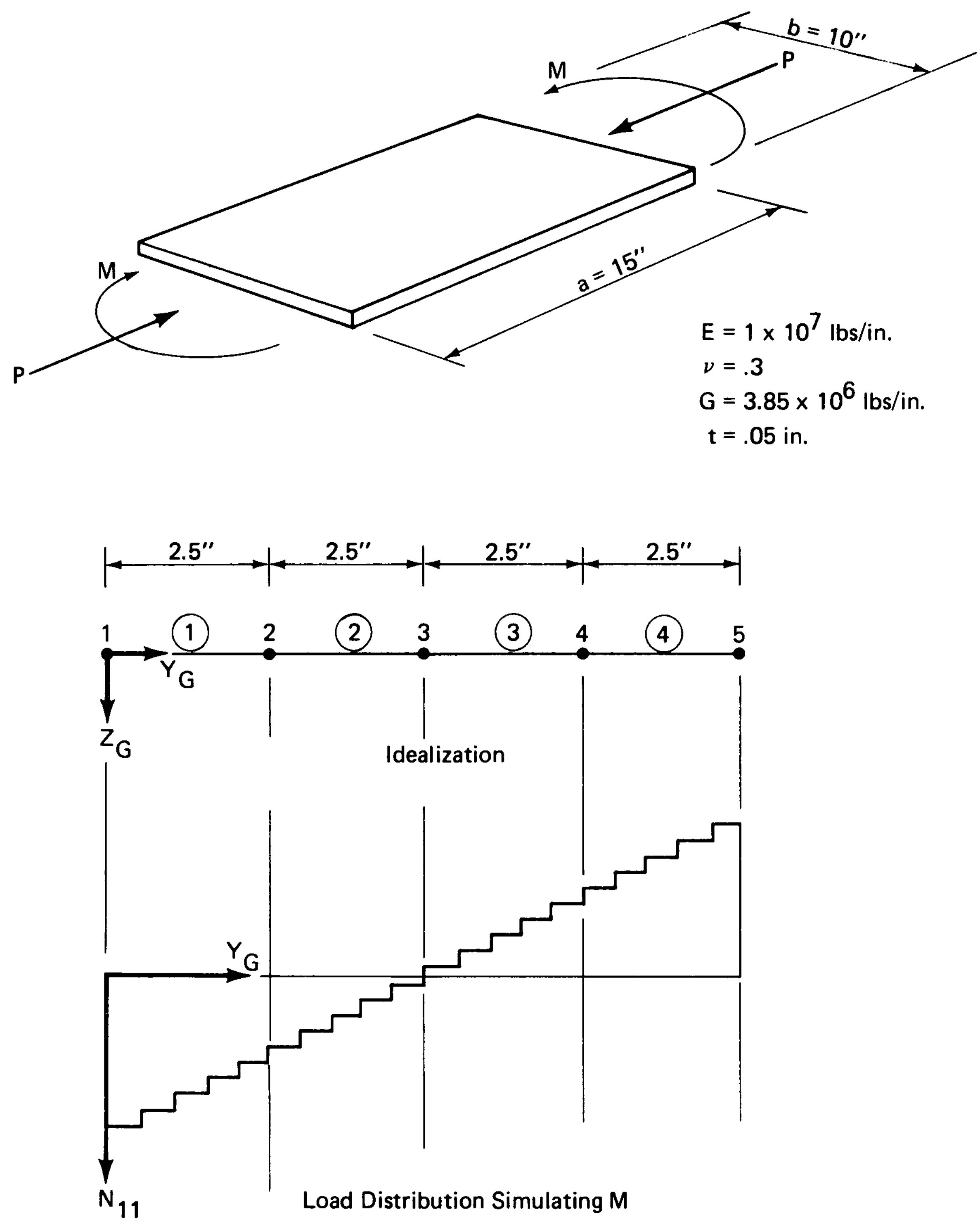


Figure 8.6 Plate Subjected to Inplane Moment and Compression

```
P R O G R A M   S 0 3 4 4 A / BUCLASP3                    NOV 01  72

THERMAL STRESS AND BUCKLING OF LAMINATED STIFFENED PANELS

LOADING              -- IN-PLANE BIAXIAL , THERMAL

BOUNDARY CONDITIONS -- (1) SIMPLY SUPPORTED ALONG EDGES PARALLEL TO THE TRANSVERSE AXIS

                       (2) ELASTICALLY RESTRAINED ALONG ANY EDGE PARALLEL TO THE LONGITUDINAL AXIS

TYPES OF ELEMENTS    -- (1) FLAT PLATE

                       (2) CURVED PLATE

                       (3) BEAM

   EXAMPLE NO.6  PLATE SUBJECTED TO INPLANE MOMENT AND COMPRESSION
```

THIS IS AN EDITTED EXAMPLE OF THE PROGRAM OUTPUT.

P R O G R A M   C O N T R O L   O P T I O N S

BUCKLING LOAD AND RELATIVE DISPLACEMENTS

NUMBER OF ITERATIONS ALLOWED IN BUCKLING CALCULATION = 100

NUMBER OF ITERATIONS USED IN EIGENVECTOR CALCULATION = 4

P R O B L E M   C H A R A C T E R I S T I C S

NUMBER OF NODES	=	5
NUMBER OF FLAT PLATE ELEMENTS	=	4
NUMBER OF CURVED PLATE ELEMENTS	=	0
NUMBER OF BEAM ELEMENTS	=	0
PANEL LENGTH	=	15.000

A N A L Y S I S   O P T I O N S

LOAD OPTION (LOADOP) = 7

WAVE NUMBER SEARCH OPTION (MOPT) = 2

INITIAL VALUE OF LONGITUDINAL WAVE NUMBER (MMI) = 2

FINAL VALUE OF LONGITUDINAL WAVE NUMBER (MMA) = 3

LOWER LIMIT FOR ROOT SEARCHING CRITERIA (NLW) = 0

UPPER LIMIT FOR ROOT SEARCHING CRITERIA (NUP) = 1

N O D A L   D A T A

	COORDINATES		BOUNDARY CONDITIONS		SPRING STIFFNESSES		
NODE	Y	Z	CODE	K(W)	K(THETA)	K(V)	K(U)
1	0.00000	0.00000	1				
2	2.50000	0.00000	0				
3	5.00000	0.00000	0				
4	7.50000	0.00000	0				
5	10.00000	0.00000	1				

S U B S T R U C T U R E   D E F I N I T I O N   D A T A

NUMBER OF SUBSTRUCTURES = 1

SUBSTRUCTURE	FIRST NODE	LAST NODE
START	1	5

FLAT PLATE ELEMENT USER NUMBER 1 USER NODE I 1 USER NODE J 2

NUMBER OF BUCKLING SUBELEMENTS = 5

NUMBER OF RELATIVE DISPLACEMENT SUBDIVISIONS = 5

MATERIAL PROPERTY INPUT OPTION = 0

MATERIAL PROPERTY INPUT FORMAT OPTION = -0

LAYER	THICKNESS	EXX	EYY	NUXY	NUYX	G
1	5.000000E-02	1.000000E+07	1.000000E+07	3.000000E-01	3.000000E-01	3.850000E+06

A-MATRIX

549450.549	164835.165	0.000
164835.165	549450.549	0.000
0.000	0.000	192500.000

B-MATRIX

-.000	-.000	0.000
-.000	-.000	0.000
0.000	0.000	-.000

D-MATRIX

114.469	34.341	0.000
34.341	114.469	0.000
0.000	0.000	40.104

I N P U T   L O A D S

SUBSTRUCTURE	SUBELEMENT	N11	N22
START	1	-4.454075E+01	-0.
	2	-3.985225E+01	-0.
	3	-3.516375E+01	-0.
	4	-3.047525E+01	-0.
	5	-2.578675E+01	-0.

PLATE ELEMENT NET OFFSETS

ELEM. NO.	START ZO	START YO	END ZO	END YO
1	0.00000	0.00000	0.00000	0.00000
2	0.00000	0.00000	0.00000	0.00000
3	0.00000	0.00000	0.00000	0.00000
4	0.00000	0.00000	0.00000	0.00000

ELEMENT TRANSFORMATION DATA

ELEM. NO.	WIDTH	TRANSFORMATION SIN(I)	COS(I)	SIN(J)	COS(J)	EL.TYPE
1	2.50000	0.00000	1.00000	0.00000	1.00000	FLAT PLATE
2	2.50000	0.00000	1.00000	0.00000	1.00000	FLAT PLATE
3	2.50000	0.00000	1.00000	0.00000	1.00000	FLAT PLATE
4	2.50000	0.00000	1.00000	0.00000	1.00000	FLAT PLATE

ELEMENT SUBSTRUCTURE ASSIGNMENT DATA

NUMBER	BLOCK
1	START
2	START
3	START
4	START

```
******************************
*                            *
*    MODE   IS   M =    2    *
*                            *
*                            *
******************************
```

EXAMPLE NO.6 PLATE SUBJECTED TO INPLANE MOMENT AND COMPRESSION

VARIABLE LOAD ON FIRST PLATE ELEMENT	NUMBER OF NEG. ON DIAGONAL	BUCKLING DETERMINANT (A*(2**B)) A	B	COMMENTS
50.00000000	1	-.74872	148	
25.00000000	0	.46735	152	
37.50000000	0	.18799	152	
43.75000000	0	.06517	152	
46.87500000	0	.12550	148	
48.43750000	1	-.31694	148	
47.65625000	1	-.09706	148	
47.26562500	0	.22216	144	
47.46093750	1	-.66673	144	
47.36328125	1	-.22262	144	
47.31445313	1	-.08064	136	
47.29003906	0	.11090	144	
47.30224609	0	.88460	140	
47.30834961	0	.43976	140	
47.31140137	0	.21736	140	
47.31292725	0	.10616	140	
47.31369019	0	.80893	136	
47.31407166	0	.36414	136	
47.31426239	0	.14175	136	
47.31435776	0	.48894	132	
47.31440544	1	-.40062	132	
47.31438160	0	.70657	128	
47.31439352	1	-.17823	132	
47.31438756	1	-.06703	132	
47.31438458	1	-.18298	128	
47.31438309	0	.26179	128	
47.31438383	0	.63041	124	
47.31438421	1	-.07179	128	
47.31438402	1	-.25915	124	

E L E M E N T   L O A D S

ELEM. NO.	N11	N22	EPS11	EPS22	P-BEAM
1	47.314384	0.	9.46287680E-05	-2.83886304E-05	
2	47.314384	0.	9.46287680E-05	-2.83886304E-05	
3	47.314384	0.	9.46287680E-05	-2.83886304E-05	
4	47.314384	0.	9.46287680E-05	-2.83886304E-05	

T O T A L   L O A D   A T   B U C K L I N G

AXIAL = 473

TRANSVERSE = 0.

EXAMPLE NO.6 PLATE SUBJECTED TO INPLANE MOMENT AND COMPRESSION

B U C K L I N G   L O A D   C O M P U T A T I O N   S U M M A R Y

CRITICAL WAVE NUMBER M = 2

M	LOAD
2	47.31438402

EXAMPLE NO.6 PLATE SUBJECTED TO INPLANE MOMENT AND COMPRESSION

```
********************************
*        EIGENVECTOR           *
*            AND               *
*  RELATIVE DISPLACEMENTS      *
********************************
*                              *
*        M =     2             *
*                              *
********************************
```

STIFFNESS MATRIX BANDWIDTH = 6

EIGENVECTOR

ITERATION NUMBER 1
NORMALIZING FACTOR 3.4745471E+00

SUBSTRUCTURE	NODE	W	THETA	V	U
START	2	-8.99468629E-01	3.03684142E-02	4.20628366E-01	4.00709375E-01
	3	-1.00000000E+00	3.63699823E-01	4.17952347E-01	3.34841856E-01
	4	-5.01184145E-01	2.87807295E-01	2.87807438E-01	1.20962283E-06

EIGENVECTOR

ITERATION NUMBER 2
NORMALIZING FACTOR 4.3771381E+07

SUBSTRUCTURE	NODE	W	THETA	V	U
START	2	8.13892665E-01	2.19988135E-01	7.46354332E-14	4.83778054E-14
	3	1.00000000E+00	-6.38930666E-02	9.30864167E-14	3.78620706E-14
	4	6.07947559E-01	-2.21766339E-01	8.67101555E-14	1.05354926E-15

EIGENVECTOR

ITERATION NUMBER 3
NORMALIZING FACTOR 4.4113157E+07

SUBSTRUCTURE	NODE	W	THETA	V	U
START	2	-8.13892665E-01	-2.19988135E-01	1.62043499E-26	6.56356820E-27
	3	-1.00000000E+00	6.38930667E-02	2.03044411E-26	4.91129494E-27
	4	-6.07947559E-01	2.21766339E-01	1.99944678E-26	-4.01879091E-30

EIGENVECTOR

ITERATION NUMBER 4
NORMALIZING FACTOR 4.4113157E+07

SUBSTRUCTURE	NODE	W	THETA	V	U

START	2	8.13892655E-01	2.19988135E-01	3.68090316E-39	9.99705563E-40
	3	1.00000000E+00	-6.38930667E-02	4.44787575E-39	6.87810503E-40
	4	6.07047550E-01	-2.21755339E-01	4.36802385E-39	-8.43327170E-41

EXAMPLE NO.6 PLATE SUBJECTED TO INPLANE MOMENT AND COMPRESSION

```
*****************************
*                           *
*   RELATIVE DISPLACEMENTS  *
*                           *
*****************************
*                           *
*         M =     2         *
*                           *
*****************************
```

START SECTION --BLOCK NO. 1

ELEMENT NO.= 1 TYPE = FLAT PLATE NODE I = 1 NODE J = 2 WIDTH = 2.5000

Y	W	V	THETA
-.2500	.00000	.00000	.38339
-.1250	.23715	.00000	.37160
0.0000	.45967	.00000	.33768
.1250	.65542	.00000	.28541
.2500	.81389	.00000	.21999

ELEMENT NO.= 2 TYPE = FLAT PLATE NODE I = 2 NODE J = 3 WIDTH = 2.5000

Y	W	V	THETA
-.2500	.81389	.00000	.21999
-.1250	.92886	.00000	.14716
0.0000	.99747	.00000	.07250
.1250	1.02013	.00000	.00058
.2500	1.00000	.00000	-.06389

ELEMENT NO.= 3 TYPE = FLAT PLATE NODE I = 3 NODE J = 4 WIDTH = 2.5000

Y	W	V	THETA
-.2500	1.00000	.00000	-.06389
-.1250	.94223	.00000	-.11926
0.0000	.85316	.00000	-.16394
.1250	.73955	.00000	-.19783
.2500	.60795	.00000	-.22177

ELEMENT NO.= 4 TYPE = FLAT PLATE NODE I = 4 NODE J = 5 WIDTH = 2.5000

Y	W	V	THETA
-.2500	.60795	.00000	-.22177
-.1250	.46410	.00000	-.23728
0.0000	.31270	.00000	-.24629
.1250	.15720	.00000	-.25068
.2500	.00000	.00000	-.25194

9.0 PROGRAM DESCRIPTION

This section is a description of the organization and function of the various routines included in BUCLASP3.

9.1 Overlay Structure

BUCLASP3 consists of a (0,0) level overlay which acts as a monitor in selection of primary overlays.

The overlay structure is:

(1) (0,0) Overlay

BUCLASP,0,0	S0344A, Monitor

(2) Primary Overlays

(a)	BUCLASP,1,0	DATAPRO, Reads all user input and outputs basic job description.
(b)	BUCLASP,2,0	THERMAL, Controls calculation of thermal displacements and stresses
(c)	BUCLASP,3,0	LOADING, Generates element stiffness matrices, merges panel stiffness matrix, and controls calculation of panel buckling load.
(d)	BUCLASP,4,0	DISPLAC, Calculates for the panel buckling load, the panel eigenvector and element relative displacements.

(3) Secondary Overlays

(a)	BUCLASP,2,1	TSTIFF, Generates panel thermal stiffness and loads matrices
(b)	BUCLASP,2,2	TDISPL, Merges loads and calculates global thermal displacements.

(c) BUCLASP,2,3 TSTRESS, Computes element stresses and complementary displacements.

Main Overlay 0,0

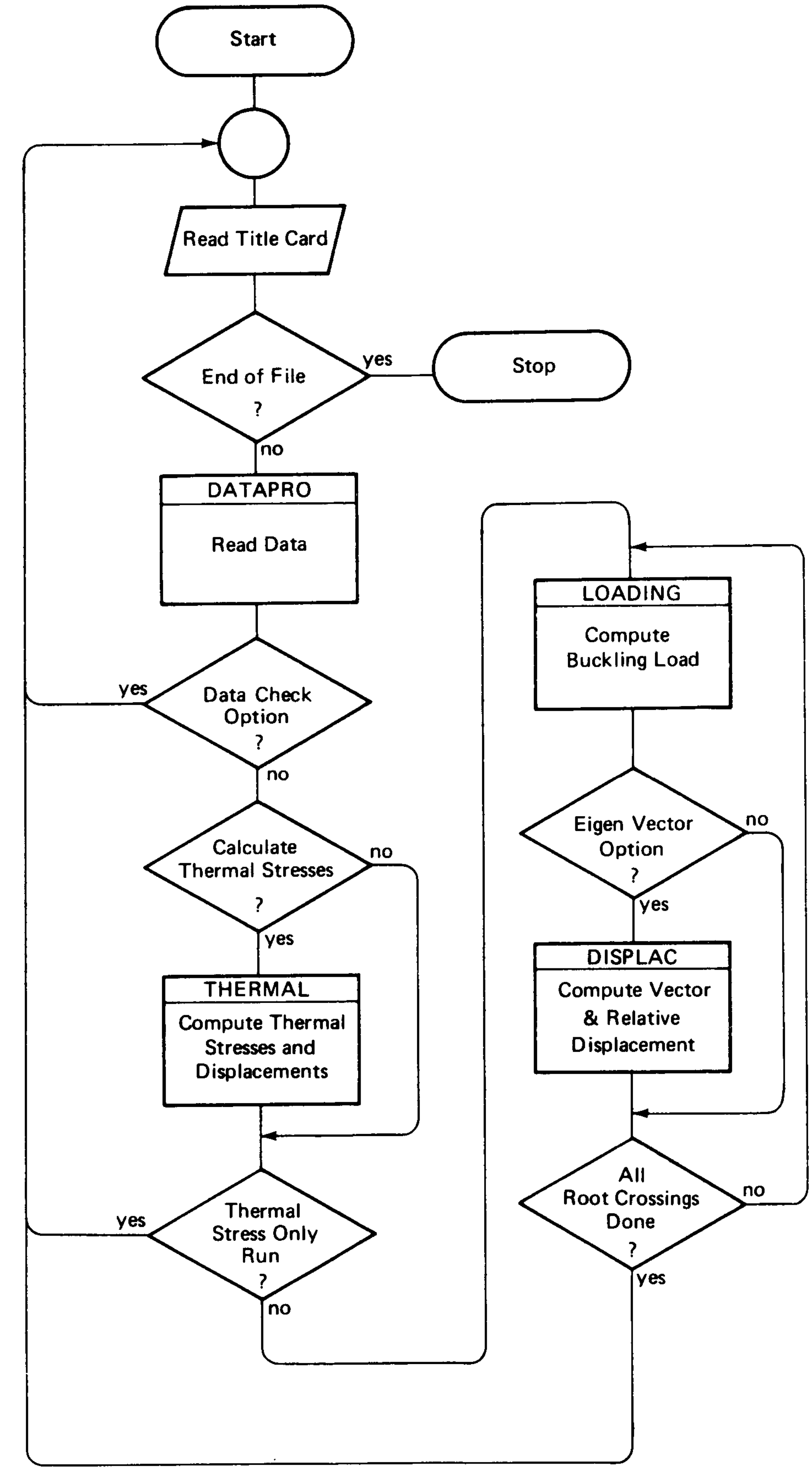
Program Name: S0344A

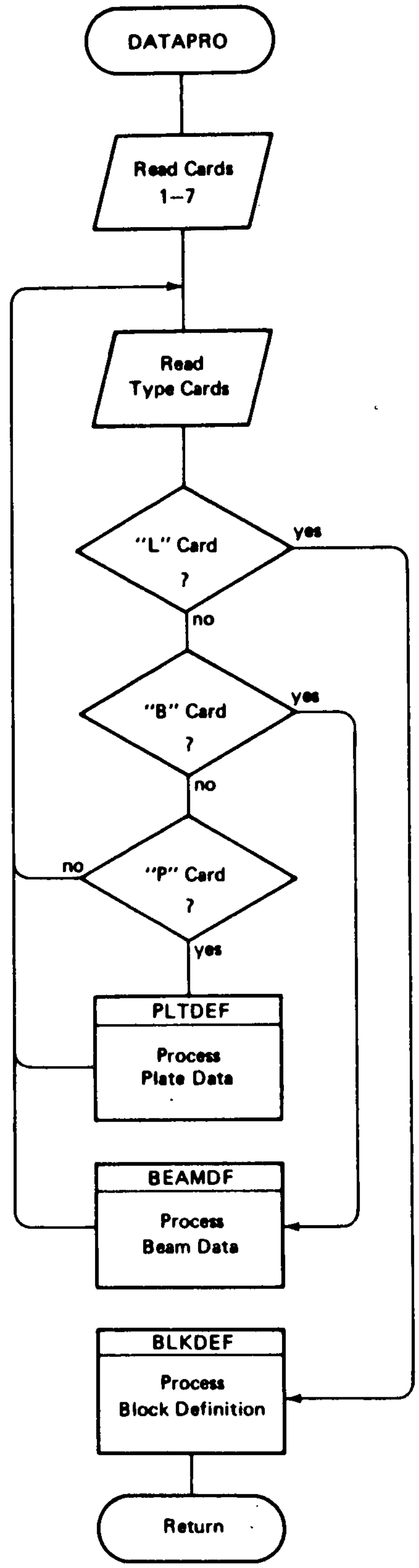
Subroutines: ELMDEF, ELMFCH, ERROR, IGAL, KELNUM, PAC, PRINT, UNPAC

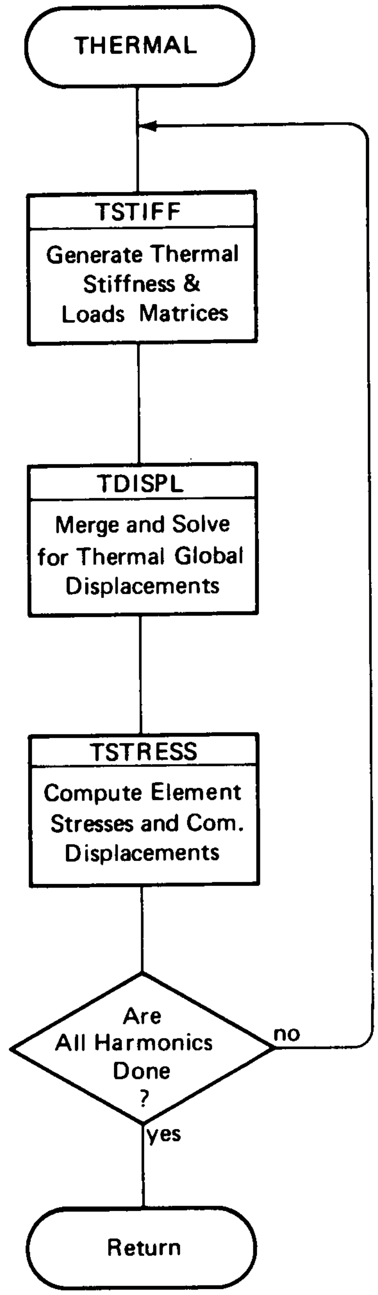
Primary Overlay 1.0		Primary Overlay 3.0		Primary Overlay 4.0	
Main Program:	DATAPRO	Main Program:	LOADING	Main Program:	DISPLAC
Subroutines:	RDVLS USERID BLKDEF PLTDEF TBPOINT NEXTC FINDIN CLNODE RDTBLE IBLKNO STRMOV TDOUT SDOUT BLKELM SORT TDATA	Subroutines:	BLKWRT LCNTRL DM PLATE SBKDT1 UPPRBD UPRBND DE DH SPGCNS STRFR SYMDET GAPUPP DB BLKGEN TRANF SBLKDT SELIM REDUVE DBLERT STORE PRDMTX PROOT HPLATE MOVX MLTPLY FPLATE FPLCOL BEAM SOLVV DT RGEN CDTM VIPDR ZARK MATZ TRANSF	Subroutines:	BANDW COMPAC BLKRED SYMBND REDUVE DIS FETCHD READTR FNLDIS TRAND

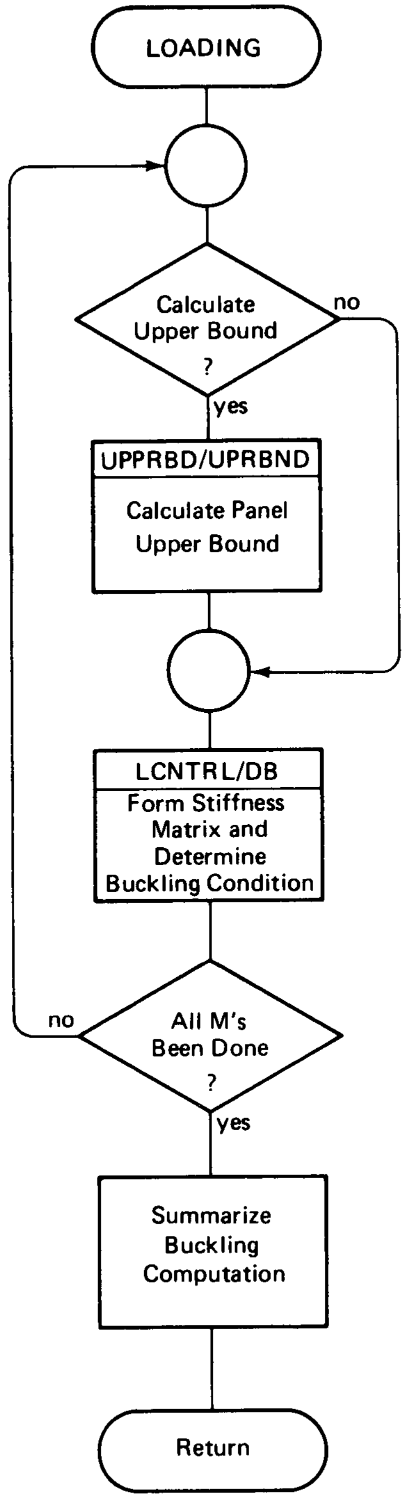
Secondary Overlay 2.1	Secondary Overlay 2.2	Secondary Overlay 2.3
Main Program: TSTIFF	Main Program: TDISPL	Main Program: TSTRESS
Subroutines: TRAND TPLATE YY YB TBEAM SMOD TRHS FMODB SPRING PLACE TRANB SPROOT DT SRGEN CDTM VIPDR SPLATE SBEAM SPLCOL SOLVE ZARK	Subroutines: TSTORE BANDW COMPAC SYMBND REDUVE	Subroutines: TRAND DTMOD LINIC FTCHDF

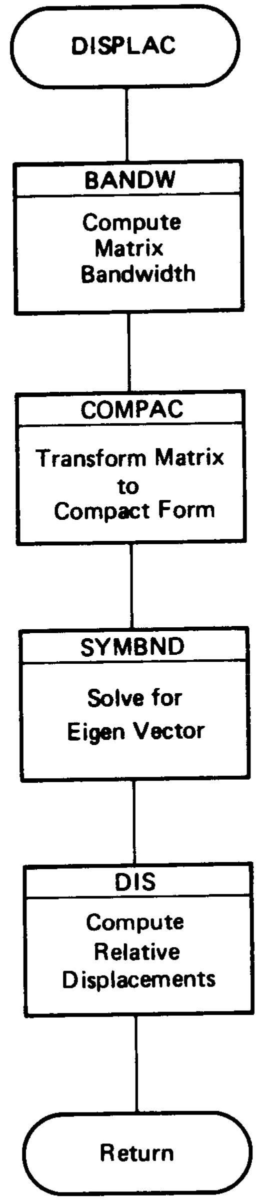
9.2 Basic Program Flow




DATAPRO
Read Cards 1–7
Read Type Cards
"L" Card ?
yes
no
"B" Card ?
yes
no
"P" Card ?
no
yes
PLTDEF
Process Plate Data
BEAMDF
Process Beam Data
BLKDEF
Process Block Definition
Return


THERMAL
TSTIFF
Generate Thermal Stiffness & Loads Matrices
TDISPL
Merge and Solve for Thermal Global Displacements
TSTRESS
Compute Element Stresses and Com. Displacements
Are All Harmonics Done ?
no
yes
Return


LOADING
Calculate
Upper Bound
?
no
yes
UPPRBD/UPRBND
Calculate Panel
Upper Bound
LCNTRL/DB
Form Stiffness
Matrix and
Determine
Buckling Condition
no
All M's
Been Done
?
yes
Summarize
Buckling
Computation
Return


DISPLAC
BANDW
Compute Matrix Bandwidth
COMPAC
Transform Matrix to Compact Form
SYMBND
Solve for Eigen Vector
DIS
Compute Relative Displacements
Return

9.3 Program/Subroutine Description

Routine	Purpose	Configurations	Tests
BANDW	BANDW calculates the bandwidth of the panel stiffness matrix for COMPAC.	Panel with	F-1
		1) Start block only	F-38
		2) Start and end blocks only	F-8
		3) Start, Repeat and End blocks	F-22
BEAM	BEAM generates stiffness matrices.	1) Beam element is input at an angle	F-23
		2) Beam element is input with offsets	F-39
BEAMDF	BEAMDF reads and processes beam material properties	1) General beam element	F-25
		2) Rectangular beam with	
		a) One lamina	F-24
		b) More than one lamina	F-23
		3) Circular beam with	
		a) One lamina	F-39
		b) More than one lamina	F-26
		4) Laminated beam input by	
		a) B-i cards	F-23
		b) Tables	F-39

Routine	Purpose	Configurations	Tests
BLKDEF	BLKDEF processes block definition node pairs to produce the row and column definition for each block and to produce the corresponding merging information.	1. Problem with	
		a) with equivalent nodes	F-23
		b) without equivalent nodes	F-22
		c) start block only	F-1
		d) start and end blocks only	F-38
		e) start, repeat and end blocks	F-22
		f) beam elements	F-23
BLKELM	BLKELM constructs a list of all elements in a substructure.	Problem with	
		1. start, repeat and end blocks	F-12
		2. plate element	F-13
		3. beam element	F-23
BLKGEN	BLKGEN forms the buckling determinant for a given load and wave number m.	1. Problem with	F-11
		a) N_{11} varying	F-15
		b) N_{11} with biaxial ratio	F-28
		c) N_{22} varying	F-19
		d) N_{22} varying with constant strain	F-20
		2. Problem with	
		a) Clamped Node	F-2
		b) Simply supported Node	F-1
		c) Free Node	F-1
		d) Sprung Node	F-11
		3. Problem with plates and beams	F-23

Routine	Purpose	Configurations	Tests
		5. LOADOP = 5	B-1
		6. LOADOP = 6	B-2
		7. LOADOP = 7	B-3
		8. LOADOP = 8	B-4
BLKRED	BLKRED reads from disk file repeat substructure of panel matrix		F-22
BLKWRT	BLKWRT writes repeat substructure of panel matrix to disk file.		F-22
CDTM	CDTM evaluates the determinant of a complex square matrix		F-1
CLNODE	For each node between the first node and the last node of a block definition pair, investigate the elements having the node as a definition node. From those elements find the smallest and largest intern or node number.	1. Plates only	F-1
		2. Plates and Beams	F-23

Routine	Purpose	Configurations	Tests
COMPAC	COMPAC takes the panel stiffness matrix as generated in the buckling computation and puts it into symmetric band format suitable for eigenvector computation with all repeat blocks present.	Panel with	
		a) Start block only	F-1
		b) Start and end blocks only	F-38
		c) Start, Repeat and end blocks	F-22
		d) Start, Repeat and end blocks in curved panel option	F-10
DATAPRO	DATAPRO read input cards 1-9, cards T, C, E, D, N. S, P, B, F, and L and process the corresponding data. The remaining data processing routines are called as required.	Problem with	
		1. Start block only	F-1
		2. Start and end blocks only	F-38
		3. Start, Repeat and End blocks	F-22
		Problem with presence of	
		4. T cards	F-39
		5. C cards	F-23
		6. E cards	F-23
		7. D cards	F-23
		8. N cards	F-23
		9. S cards	F-23
		10. B cards	F-23
		11. P cards	F-23
		12. F cards	F-22

Routine	Purpose	Configurations	Tests
		13. L cards	F-22
		Problem with	
		14. Beam element	F-23
		15. Flat plate element	F-23
		16. Curved plate element	F-21
		User Diagnostics	F-40 - F-90
DB	DB controls the evaluation of the panel buckling load		F-1
DBLERT	DBLERT is the error trap routine for PROOT encountering a double root.		Inspection
DE	DE controls merging and buckling condition determination of subelement approximation of an element.	Problem with	
		1. LOADOP = 6 or 8	B-2
		2. LOADOP = 5 or 7	B-3
		3. 2 subelements per element	B-1
		4. 3 subelements per element	B-9
		5. Offsets at left end of element	5-5
		6. Offsets at right end of element	5-5

Routine	Purpose	Configurations	Tests
DH	DH generates and evaluates the determinant of the retained nodal stiffness of a plate.	Thermal problem with	
		1. LOADOP = 5, 7	B-3
		2. LOADOP = 6, 8	B-4
		3. Plate with	
		a) Simply supported node	B-9
		b) Clamped node	Inspection
		c) Free node	B-9
		d) Sprung node	Inspection
DIS	DIS computes the relative displacements of the deformed panel.	1. Panel with	
		a) Start block only	F-1
		b) Start and End blocks only	F-38
		c) Start, Repeat and End blocks	F-22
		2. Problem with	
		a) Plate with zero B-matrix	F-29
		b) Plate with non-zero B-matrix	F-7
DISPLAC	DISPLAC controls the execution BUCLASP, 3,0 overlay which computes panel eigenvector and element relative displacements.		Inspection F-1

Routine	Purpose	Configurations	Tests
DM	DM generates and evaluates the determinant of the retained node on a plate with a non-interior node.	1. a) N_{11} varying	NF-11
		b) N_{11} varying with non-trivial biaxial ratio	F-15
		c) N_{22} varying	F-28
		2. Plate with	
		a) Simply supported node	F-2
		b) Clamped node	F-1
		c) free node	F-1
		d) Sprung node	F-11
DT	DT calculates the determinant of the coefficient matrix for the equilibrium equations.	1. Flate plate with non-zero B-matrix	F-7
		2. Flate plate with zero B-matrix	F-29
DTMOD	DTMOD performs backsubstitution for deflection on reduced out nodes.	Thermal plate problem with boundary condition	S-1

Routine	Purpose	Configurations	Tests
ELMDEF	ELMDEF retrieves for an element in a substructure its type, global number, local number and plate lamina number.	Problem with	
		1. Plate in	
		a. Start Substructure	F-22
		b. Repeat Substructure	F-22
		c. End Substructure	F-22
		2. Beam in	
		a. Start Substructure	F-22
		b. Repeat Substructure	F-22
		c. End Substructure	F-22
ELMFCH	ELMFCH retrieves from element list element type, plate lamina number and element local number given element global number.	Problem with	
		1. Beam element	F-22
		2. Plate element	F-22
ERROR	ERROR prints name of routine where error was detected and error number and calls exit.		Inspection F-40
EVALUE	The routine EVALUE extracts the lowest eigenvalue from a general eigenproblem of up to order 15 for the GALERKIN method.		F-17

Routine	Purpose	Configurations	Tests
FETCHD	From the panel eigenvector, fetch the nodal deflection component for an interior node.	1. Node is in row	
		a) Start block	
		a.1) Is part of an element with a node in the repeat block. (Interrelationship elements defined)	F-22
		a.2 Is not	F-22
		b) Repeat block	F-22
		c) End block	F-22
FINDIN	a) For the first node in a block definition pair, find the smallest interior internal node larger than the first node.		F-22
	b) For the last node in a block definition pair find the largest interior internal node smaller than the last node.		

Routine	Purpose	Configurations	Tests
FMODB	FMODB and FMOD produce final plate	Problem with thermally loaded plate with	
	thermal loads for merging	1. left node constrained	S-1
		2. Right node constrained	S-1
		3. Both nodes unconstrained	S-1
FNLDIS	For a beam or plate element obtain	1. Beam element	F-23
	the element displacement vector by	2. Plate element	
	fetching the element nodal	a) left node reduced out	F-28
	displacement vector or backsubsti-	b) right node reduced out	F-28
	tuting for reduced out nodal	c) both nodes interior	F-1
	components of plate elements.		
	The W_i's are solved for plate elements.		
FPLATE	FPLATE (1) calculates the P-root	1. Plate element with non-zero B matrix	F-1
	normalization factor for the set	2. Plate element with zero B matrix	F-29
	of P roots for a plate element,		
	(2) puts together the deflection		
	and force matrices for the plate.		

Routine	Purpose	Configurations	Tests
FPLCOL	FPLCOL generates for one P-value the columns of the deflection and force matrices for the left and right side of a plate element.	1. Curved plate element with non zero B-matrix. N_{11} varying	F-31
		2. Curved plate element with zero B-matrix. N_{11} varying	F-30
		3. Flate plate element with non zero B-matrix. N_{11} varying	F-32
		4. Flate plate element with zero B-matrix. N_{11} varying	F-34
		5. Curved plate element with non zero B-matrix. N_{22} varying	F-7
		6. Curved plate element with zero B-matrix. N_{22} varying	F-37
		7. Flate plate element with non zero B-matrix. N_{22} varying	F-29
		8. Flate plate element with zero B-matrix. N_{22} varying	F-28

Routine	Purpose	Configurations	Tests
FTCHDF	FTCHDF retrieves from the panel thermal displacement vector the nodal deflection component for an interior node.	Thermal problem with node in	
		1. Start substructure	S-4
		2. Repeat substructure	
		a. Element connecting to start substructure	S-4
		b. Element connecting to end substructure	S-4
		3. End substructure	
		a. Element connecting to repeat substructure	S-4
		b. Element not connecting to repeat substructure	S-4
GAPUPP	GAPUPP uses Galerkin's Method to obtain an approximation to an individual plate's critical load.	1. Flate plate	
		a) N_{11} varying	F-11
		b) N_{22} varying	F-28
		c) Biaxial ratio on	
		1) first plate element	F-15
		2) subsequent plate element	F-16
		2. Curved plate	F-16

Routine	Purpose	Configurations	Tests
HPLATE	HPLATE produces the deflection, force and stiffness matrices for a subdivided plate element.	Problem with	
		1. Curved plate	F-21
		2. Flat plate	F-22
		3. Offsets at left end	S-5
		4. Offsets at right end	S-5
		5. LOADOP = 5	F-11
		6. LOADOP = 2,3	F-28
		7. LOADOP = 5,7	B-1
		8. LOADOP = 6,8	B-3
IBLKNO	Obtain for an interior, internal node the corresponding row block number.	1. Start block only	F-1
		2. Start and End block only	F-38
		3. Start, Repeat and End blocks	F-8
IGAL	IGAL supplies information as to the length of blank common in each overlay.		Inspection

Routine	Purpose	Configurations	Tests
KELNUM	KELNUM calculates for an element its local and global thermal element number.	Thermal problem with	
		1. Beam in	
		a. Start structure	S-5
		b. Repeat structure	S-4
		c. End structure	S-5
		2. Flat plate in	
		a. Start structure	S-4
		b. Repeat structure	S-4
		c. End structure	S-4
		3. Curved plate in	
		a. Start structure	S-5
		b. Repeat structure	S-5
		c. End structure	S-5
LCNTRL	LCNTRL finds for an interval of real numbers the buckling load (if it exists) in the internal to a specified tolerance using a bisection technique.	1. No buckling load found	Inspection
		2. Buckling load found	
		3. Double root encountered at a trial load	
		4. Zero determinant encountered at a trial load.	

Routine	Purpose	Configurations	Tests
LININC	LININC controls print line for thermal stress output.		S-1
LOADING	LOADING controls the computation of the critical load and wave number for the panel.	1. Various wave number search options	
		a) 1	F-37
		b) 2	F-1
		c) 3	F-36
		d) 4	F-39
		2. Upper Bound Input	F-37
		3. Upper Bound Calculated.	F-11
		4. Upper Bound Calculation Option Only	F-11
		5. Problem with Beams, Flate and Curved Plates	F-40
MATZ	MATZ zeros out a specified block of rows and columns of a matrix.		F-1
MLTPLY	MLTPLY performs product of two 8 X 8 matrices.		B-1
MOVX	MOVX transfers force and deflection matrices.		B-1

Routine	Purpose	Configuration	Tests
NEXTC	NEXTC returns next character on table pointer card.	1. Test for end-of-file 2. Illegal character	F-37
PAC (A, I, J, B)	PAC will pack the (J-I+1) rightmost bits of the word B into the bit positions I-J of the word A. The remaining bits of A are unchanged.		F-1
PLACE	PLACE merges a 4 X 4 element submatrix associated with a node pair into the appropriate sub-block of the panel thermal stiffness matrix.	Thermal problem with 1. Start substructure only 2. Start and End substructures only 3. Start, Repeat and End substructures	 S-1 S-6 S-5
PLTDEF	PLTDEF reads and processes plate definition data to produce plate lamina extensional, coupling and bending stiffness matrices. PLTDEF produces transformation matrices used in strain and load calculation.	Problem with 1. Lamina stress-strain input a) by P-2 card b) by Table 2. Engineering constants input a) by P-1 card b) by Table 3. Non-zero B matrix a) have same radius, loads and stiffness	 F-37 F-37 F-1 F-37 F-30 F-40

Routine	Purpose	Configuration	Tests
		b) have different radius, loads and stiffness	F-32
		4. Zero B matrix	F-33
PRDMTX	PRDMTX reduces out the effects of a constrained node for a plate element.	1. The element nodal intercoupling matrix is singular	Inspection
		2. The element nodal intercoupling matrix is non singular	F-1
PRINT	PRINT prints a rectangular matrix up to 8 columns at a time and all rows.		F-81
PROOT	PROOT calculates the roots of the equilibrium equations for a plate element.	1. Plate element with non-zero B-matrix	F-27
		2. Plate element with zero B-matrix	F-27
RDTBLE	Reading from card images (columns 11-80) floating point data in a free-field format with commas and end of physical card as field delimeters. Slash (/) is the logical card delimeter limit of fourteen significant digits.	1. 2 or more physical cards used 2. E format data 3. E format data with 14 signicant digits 4. F format data 5. F format data with 14 signicant digits 6. Error exits a) end-of-file, missing slash	F-37 and subroutine tests

Routine	Purpose	Configuration	Tests
		b) Illegal data, bad character, too many characters. c) Table size limit exceeded d) No data input	
RDVLS	Reads pairs of integers in a 2(2X, I3) format from card images and stores non zero pairs in an array.	1. Eof of file encountered 2. Maximum of receiving array is exceeded.	F-1
READTR	Read from a binary file a nodal or elemental transformation matrix.	1. Nodal transformation requested 2. Elemental transformation requested	F-1 F-1
REDUVE	Reduces one vector into another vector COMPASS Routine		F-1
RGEN	RGEN generates the elements of the coefficient matrix for the equilibrium equations for the current plate element.	1. Curved plate element with zero B-matrix. N_{11} varying 2. Flate plate with non-zero B-matrix. N_{11} varying 3. Flate plate with zero B-matrix. N_{11} varying	F-7 F-37 F-29

Routine	Purpose	Configuration	Tests
		4. Curved plate with non-zero B-matrix. N_{11} varying	F-28
		5. Curved plate element with zero B-matrix. N_{22} varying	F-31
		6. Flate plate with non-zero B-matrix. N_{22} varying	F-30
		7. Flate plate with zero B-matrix. N_{22} varying	F-32
		8. Curved plate with non-zero B-matrix. N_{22} varying	F-34
SBEAM	SBEAM generated beam element stiffness matrix	1. Thermal beam element is input at an angle	S-5
		2. Thermal beam element is input with offsets	Inspection
SBLKDT	SBLKDT computes the determinant of a symmetric matrix which has an overlapping and repeated block structure (where the blocks differ in content)	Symmetric Matrix with	
		1. Start block only	F-1
		2. Start and end blocks only	F-38
		3. Start, 1 repeat and end blocks	F-8
		4. Start, 2 repeat and end blocks	F-22

Routine	Purpose	Configuration	Tests
SBKDT1	SBKDT1 calculates the determinant of a symmetrix matrix for upper bound calculation.		F-17
SDOUT	SDOUT outputs to scratch disk the load data by substructure.	Externally loaded problem with	
		1. Start substructure only	B-1
		2. Start and end substructures only	B-22
		3. Start, repeat and end substructures	B-21
		4. Plate element	B-21
		5. Beam element	B-21
SELIM	SELIM performs a Gaussian reduction on a symmetric matrix.	1. Non-zero pivot	F-1
		2. Zero pivot	Inspection
SMOD	SMOD performs steps of reduction of plate elemental stiffness with constrained node.	Thermal problem with plate with a boundary condition	S-1
SOLVE	SOLVE solves the matrix problem $X \cdot A = B$ for X	1. X^T is non-singular	S-1
		2. X is singular	Inspection

Routine	Purpose	Configuration	Tests
SOLVV	Solves matrix problem X•A = B for X or A•X = B.	1. X^T is non-singular	F-1
		2. X^T is singular	Inspection
		3. X is singular	B-1
		4. X is not singular	Inspection
SORT	SORT sorts list of integers from low to high.		B-1
SPGCNS	SPGCNS produces the spring constants for the end subelements of an element.	Problem with LOADOP = 5,6,7,8 where element has	
		1. interior node	B-9
		2. simply supported node	B-9
		3. clamped node	Inspection
		4. free node	B-9
		5. sprung node	Inspection
SPLATE	SPLATE calculates the P-root normalization factor for the set of P roots for a plate element and puts together the deflection and force matrices for the plate.	1. Plate element with non-zero B-matrix	S-1
		2. Plate element with zero B-matrix	S-2

Routine	Purpose	Configuration	Tests
SPLCOL	SPLCOL generates for one P-value the columns of the deflection and force matrices for the left and right sides of a plate element.	Thermal problems with	
		1. Curved plate element with non-zero B-matrix	S-2
		2. Curved plate element with zero B-matrix	S-3
		3. Flat plate element with non-zero B-matrix	S-7
		4. Flat plate element with zero B-matrix	S-1
SPRING	SPRING generates the nodal spring stiffnesses for a plate element.	Thermal problem with plate with	
		1. Both nodes interior	S-1
		2. Free node	Inspection
		3. Clamped node	Inspection
		4. Simply supported node	S-1
		5. Sprung node	S-3
SPROOT	SPROOT calculates the roots of the equilibrium equation for a plate element in a thermal environment.	1. Plate element with non-zero B-matrix	S-1
		2. Plate element with zero B-matrix	S-2
		3. Plate element which is repeated.	S-1

Routine	Purpose	Configuration	Tests
SRGEN	SRGEN generates the elements of the coefficient matrix for the equilibrium equations for the current thermal plate element.	1. Curved plate element with zero B-matrix	S-3
		2. Curved plate element with non-zero B-matrix	S-2
		3. Flat plate element with zero B-matrix	S-1
		4. Flat plate element with non-zero B-matrix	S-7
STORE	STORE merges a 4 X 4 element submatrix associated with a node pair into the appropriate subblock of the panel stiffness matrix.	Panel with	
		1. Start block only	F-1
		2. Start and end blocks only	F-38
		3. Start, repeat and end blocks	F-22
STRFR	STRFR stores nodal stiffness components into compact storage scheme for element.	Problem with LOADOP = 5,6,7,or 8.	B-9
STRMOV	Moves characters starting at a position in one array to a different position in another array.	1. Starting array is more than one word	Inspection
		2. Receiving array is more than one word	F-37

Routine	Purpose	Configuration	Tests
SYMBND	Linear equation solver for a symmetric band matrix	1. Zero pivot encountered 2. All non zero pivots	Inspection F-1
SYMDET	SYMDET counts the number of negative occuring on the diagonal of a banded matrix during decomposition.		B-9
S0344A	S0344A controls the execution of BUCLASP3 through its primary overlays, provides central processor time usage information and controls various n/n+1 root crossing searches.	1. Multiple Data Sets 2. Data Check Option Only 3. Buckling Option only 4. Buckling and Eigenvector option 5. Multiple root searching option 6. Thermal Stress 7. Thermal Buckling	 F-41 F-36 F-1 F-35
TBEAM	TBEAM generates thermal loads for a beam element.	Problem with thermally loaded beam	S-5
TBPOINT	TBPOINT reads the table pointer card following P and B cards and constructs an array of pointers.	1. Repeat option left of slash 2. Repeat option right of slash	F-37

Routine	Purpose	Configuration	Tests
TDATA	TDATA reads and preprocesses thermal data for beam and plate elements.	Problem with	
		1. General beam	S-5
		2. Rectangular beam	Inspection
		3. Circular beam	Inspection
		4. Plate with	
		a. Thermal data in z-direction at mid plane	S-7
		b. Thermal data in z-direction by coefficients	S-1
TDISPL	TDISPL controls the merging of the panel thermal right hand side and coefficient matrices and the computation of the global thermal displacements	Thermal problem with	
		1. Start substructure only	S-1
		2. Start and end substructures only	S-6
		3. Start, repeat and end substructures	S-5
		4. Plate element	S-5
		5. Beam element	S-5
TDOUT	TDOUT outputs to scratch disk the thermal data by substructure	Thermal problem with	
		1. Start substructure only	S-1
		2. Start and end substructures only	S-6
		3. Start, repeat and end substructures	S-5
		4. Plate element	S-5
		5. Beam element	S-5

Routine	Purpose	Configuration	Tests
THERMAL	THERMAL controls execution of thermal stress overlays.	1. Check print option ON	Inspection
		2. Check print option OFF	S-5
TPLATE	TPLATE generates thermal loads for a plate element.	Thermal problem with	
		1. Flat plate	S-1
		2. Curved plate	S-2
TRANB	TRANB transforms a nodal stiffness matrix from the local axis to the global axis.		S-1
TRAND	Transforms nodal deflection component from the global axis to the local axis.		F-1
			F-2
			F-3
			F-4
			F-5
			F-6
			F-8
			F-9

Routine	Purpose	Configuration	Tests
TRANF	TRANF transforms nodal stiffness matrix from the local axis to the global axis for plate elements with non-interior node.		F-1 F-2 F-3 F-4 F-5 F-6 F-8 F-9
TRANSF	TRANSF transfers specified blocks of rows and columns from one array to another array.		F-1
TRHS	TRHS produces the backsubstitution matrix for a plate element with thermal loads and a constrained node.	Thermal problem with plate with a boundary condition with thermal loads.	S-1
TSTIFF	TSTIFF controls the generation of the stiffness and loads matrix for the thermal global displacements and the merging of the stiffness matrix.	Thermal problem with	
		1. Start substructure only	S-1
		2. Start and end substructures only	S-6
		3. Start, repeat and end substructures	S-5
		4. Plate element	S-5
		5. Beam element	S-5

Routine	Purpose	Configuration	Tests
TSTORE	TSTORE merges nodal components of element right hand side matrices into the global right hand side matrix.	Thermal problem.	S-1
TSTRESS	TSTRESS computes the elemental stresses and complimentary displacements. TSTRESS either (1) calculates thermal stresses at specified points for each element or (2) calculates average N_{11} and N_{22} for each subdivision of a plate element or the average N_{11} for a beam element due to thermal load.	Thermal problems with	
		1. Start substructure only	S-1
		2. Start and end substructures only	S-6
		3. Start, repeat and end substructures	S-5
		4. Plate element	
		a. Thermal stress mode	S-1
		b. Thermal buckling mode	S-5
		c. with zero B-matrix	S-1
		d. with non-zero B-matrix	S-2
		5. Beam element	
		a. Thermal stress mode	S-1
		b. Thermal buckling mode	S-5
UNPAC (A, I, J, B)	UNPAC extracts bits I-J from the word A and places the right-adjusted into the word B. The remaining bits of B are set to zero.		Inspection

Routine	Purpose	Configuration	Tests
UPPRBD	UPPRBD calculates the upper bound for the critical load.	1. Problems with	
		a) beam elements	F-27
		b) similar plate with	
		1) same boundary condition - with same and different widths	F-33/F-27
		2) different boundary condition	F-27
		3) same spring stiffness - with same and different widths	F-33/F38
		4) different spring stiffness	F-38
		c) non neglected plate elements with non-interior node	F-27
		2. Plate problems with	
		a) N_{22} varying	F-28, F-36
		b) N_{11} varying N_{22I}	
		1) Plate element J is affected 1st, plate element is affected	F-11
		2) Plate element J is not affected 1st, plate element is affected	F-12
		3) Plate element J is affected 1st, plate element is not affected	F-13
		4) Plate element J is not affected 1st, plate element is not affected	F-14

Routine	Purpose	Configuration	Tests
		5) Biaxial ratio Z0, plate element J is affected, first plate element is affected	F-15
		6) Biaxial ratio Z0, plate element J is not affected, first plate element is affected.	F-16
		7) Biaxial ratio Z0, plate element J is affected, first plate element is not affected	F-17
		8) Biaxial ratio Z0, plate element J is not affected, first plate element is not affected	F-18
UPRBND	UPRBND calculates the panel upper bound for LOADOP = 5,6,7,8.	Problem with	
		1. Start substructure only	B-1
		2. Start and end substructure only	B-22
		3. Start, repeat and end substructures	B-21
		4. LOADOP = 5 or 7 where	
		a. Subelement is already buckled	B-6
		b. reduced subelement is already buckled	B-7
		c. workable	B-5
		5. LOADOP = 6 or 8	

Routine	Purpose	Configuration	Tests
		a. subelement $N_{11} \neq 0$ and $N_{22} \neq 0$	B-9
		b. subelement $N_{11} = 0$ and $N_{22} \neq 0$	B-10
		c. subelement $N_{11} \neq 0$ and $N_{22} = 0$	B-12
		d. subelement $N_{11} = 0$ and $N_{22} \neq 0$	B-11
		e. element $N_{11} = 0$ and $N_{22} \neq 0$	B-16
		f. subelement buckled	B-13
		g. reduced subelement buckled	B-14
			B-15
			B-17
			B-18
			B-19
			B-20
USERID	Converts user ID's for nodes, plate elements and beam elements to internal ID's and vice versa.	1. Invalid type for ID search	Inspection
		2. Invalid search option	
		3. User ID not found	F-64
		4. Internal ID not valid	
VIPDR	VIPDR produces the inner product of 2 vectors in double precision.		F-1

Routine	Purpose	Configuration	Tests
YB	YB computes the particular solution of a plate elemental nodal displacement at Y = -B/2 or Y = b/2	Thermal problem with plate.	S-1
YY	YY generates inter-element forces due to temperature change from particular solution for plate element along X-axis at Y = b/2 or Y = -b/2.	Thermal problem with plate.	S-1
ZARK	To find N zeros of an arbitrary complex - valued function of a complex variable.		F-1

10.0 PROGRAM VALIDATION

The program, BUCLASP3 was validated by running various data sets such that all major logic paths were tested. The validation is divided into two categories:

a. Functional Tests
b. Inspection

Listed below is the functional tests and their characteristics. Section 9.3 states for each program/subroutine the test(s) used.

10.1 Input Option Functional Test Correlation

Card	Field	Option	Test
1	1	Data Set Title	F-1
2	1	IPC(1) = 0	F-1
		IPC(1) = 1	F-81
	2	IPC(2) = 0	F-1
		IPC(2) = 1	F-82
	3	IPC(3) = 0	F-1
		IPC(3) = 1	F-83
	4	IPC(4) = 0	F-1
		IPC(4) = 1	F-83
	5	IPC(5) = 0	F-1
		IPC(5) = 1	F-84
	6	IPC(6) = 0	F-1
		IPC(6) = 1	F-85
	7	IPC(7) = 0	F-1
		IPC(7) = 1	F-86
	8	IPC(8) = 0	F-1
		IPC(8) = 1	F-87
	9	IPC(9) = 0	B-1
		IPC(9) = 1	B-23

Card	Field	Option	Test
2	10	IPC(10) = 0	B-1
		IPC(10) = 1	B-23
	11	IPC(11) = 0	B-1
		IPC(11) = 1	B-23
	12	IPC(12) = 0	B-1
		IPC(12) = 1	B-23
	13	IPC(13) = 0	B-1
		IPC(13) = 1	B-23
	14	IPC(14) = 0	B-1
		IPC(14) = 1	B-23
3	1	JPC(1) = 0	F-1
		JPC(1) = 1	F-41
	2	JPC(2) = 0	F-36
		JPC(2) = 1	F-1
	3	JPC(3) = 0	F-1
		JPC(3) = 1	F-41
	4	JPC(4) = n	F-89
	5	JPC(4) = k	F-37

Card	Field	Option	Test
3	6	Default thermal input = 1	S-7
		Default thermal input = 2	S-1
	7	Default value for number of subelements	B-23
	8	First Fourier Harmonic for printing	S-1
	9	Last Fourier Harmonic for printing	S-1
	10	Output option for stress NUMX > 0	S-1
		Output option for stress NUMX < 0	S-8
4	1	Number of Nodes	F-1
	2	Number of Beams	F-41
	3	Number of Flat Plates	F-41
	4	Number of Curved Plates	F-41
	5	Section Length	F-1
	6	Load or Strain Value	F-19
	7	Biaxial Ratio	F-15

Card	Field	Option	Test
5	1	Load Option = 4	S-1
		= 5	B-1
		= 6	B-2
		= 7	B-3
		= 8	B-4
	2	Wave Number Option = 1	F-37
		= 2	F-1
		= 3	F-36
		= 4	F-39
	3	Loop Start Value	F-1
	4	Loop End Value	F-1
	5	Lower limit for root search	F-35
	6	Upper limit for root search	F-35
	7	Default number of subdivision	
		= blank	F-1
		= n	F-37
	8	Lower bound load	F-37
	9	Upper bound load	F-37
6	1-16	M-list values	F-36
7	1-14	M-list values	F-37

Card	Field	Option	Test
T-1	variable	Thickness Table	F-37
T-2	variable	Material Table	F-37
C	1-9		F-27
E	1-9		F-27
N	1	Letter N	F-2
	2	User Node Number	F-2
	3	Nodal Boundary Condition	
		= blank	F-2
		= 1	F-2
		= 2	F-1
		= 3	F-1
		= 4	F-11
	4	Y-coordinate	F-2
	5	Z-coordinate	F-2
D	1	Letter "D"	F-1
	2	Number of substructures	F-1
	3-8	Substructure Node Pairs	
		start only	F-1
		start and end only	F-38
		start, repeat, and end	F-22

Card	Field	Option	Test
S	1	Letter "S"	F-11
	2	User Node ID	F-11
	3	w component	F-11
	4	θ component	F-11
	5	v component	F-11
	6	u component	F-11
F	1	Letter "F"	F-22
	2	User Plate ID	F-22
	3	OFF1	F-22
	4	OFF2	F-22
	5	OFF3	F-22
	6	OFF4	F-22
P	1	Letter "P"	F-1
	2	User Plate ID	F-1
	3	Node I	F-1

Card	Field	Option	Test
P	4	Node J	F-1
	5	Plate Type = 1 Flat	F-1
		= 2 Curved	F-30
	6	Element offset = 0 No	F-1
		= 1 Yes	F=22
	7	Number of laminas	F-1
	8	Input mode = 0 P-1, or P-2 card	F-1
		= 1 Table	F-37
	9	N_{22} load switch = 0 affected	F-38
		= 1 not affected	F-36
	10	Number of subdivisions	F-37
	11	Type of material properties	
		= 0 Engineering Constants	F-37
		= 1 Q matrix	F-37
	12	Local plate thermal input = 0	S-1
		= 1	S-7
		= 2	B-23
		= 3	B-23
	13	Load input option = 0	B-3
		= 1	B-24
	14	Substructure assignment	S-1

Card	Field	Option	Test
P	15	Number of subelements	B-23
	16	Curved Plate Radius	F-21
P-1	1	T	F-1
	2	E_{11}	F-1
	3	E_{22}	F-1
	4	RNUA	F-1
	5	G_{12}	F-1
P-2	1	T	F-37
	2	Q_{11}	F-37
	3	Q_{12}	F-37
	4	Q_{22}	F-37
	5	Q_{66}	F-37
P-3	1	TX	S-7
	2	TYA	S-7
	3	TYB	S-7
	4	TYC	S-7

Card	Field	Option	Test
P-3	5	TZA	S-1
	6	TZB	S-1
	7	TZC	S-1
P-4	1	ALPHX	S-7
	2	ALPHY	S-7
	3	TZ	S-7
P-5	1-8	N_{11} input	B-1
P-6	1-8	N_{22} input	B-1
B	1	Letter "B"	F-23
	2	User Beam ID	F-23
	3	Beam Node	F-23
	4	Type of Beam = 1	F-25
		= 2	F-24
		= 3	F-26
	5	Number of layers	F-23

Card	Field	Option	Test
B	6	Input Mode = 0 B-1, B-2 or B-3 card	F-23
		= 1 By tables	F-39
	7	Thermal Input Option = 0	S-5
		= 1	S-9
	8	Load Input Options = 0	B-1
		= 1	B-24
	9	Beam Angle	F-23
	10	Beam Area	F-23
B-1	1	E-Modulus	F-25
	2	G-Modulus	F-25
	3	Moment about local yy-axis	F-25
	4	Moment about local zz-axis	F-25
	5	Warping constant	F-25
	6	Torsion constant	F-25
	7	Y offset	F-25
	8	Z offset	F-25

Card	Field	Option	Test
B-2	1	Thickness	F-23
	2	E-Modulus	F-23
	3	G-Modulus	F-23
	4	Beam width	F-23
B-3	1	Radius	F-26
	2	E-Modulus	F-26
	3	G-Modulus	F-26
B-4	1	MTY	S-10
	2	MTZ	S-10
	3	PIT	S-10
B-5	1	TXO	S-11
	2	TAZ	S-11
	3	TBZ	S-11
	4	TCZ	S-11

Card	Field	Option	Test
B-6	1	ALPHX	S-11
	2	TY	S-11
B-7	1	ALPHX	S-11
	2	TR	S-11
B-8	Axial load		B-21
L	1	Letter "L"	F-1

10.2 Functional Test Descriptions

Test	Characteristics
F-1	1. Flat Panel at 90° SS - Free 2. Buckling and eigenvector solution 3. MØPT = 2 4. Flat Plates with a. left node reduced out b. both nodes interior c. right node reduced out 5. Input by P-1 cards 6. Simply-supported node
F-2	1. Flat Panel at 90° C - Free 2. Clamped node 3. Free node
F-3	1. Flat Panel at 0° angle SS - Free
F-4	1. Flat Panel at 0° angle C - Free
F-5	1. Panel at angle (non-orthogonal) SS - Free B.C.
F-6	1. Panel at angle (non-orthogonal) C - Free B.C.
F-7	1. Flat plate with non-zero B matrix
F-8	1. Curved panel at angle (1)
F-9	1. Curved panel at angle (2)
F-11	1. N_{11} varying 2. N_{22I} Input

10.2 F-11 Continued ...

3. First Plate Affected
4. J^{th} Plate Affected
5. Sprung B.C.

(J is the critical element for panel upper bound.)

F-12

1. N_{11} Varying
2. N_{22I} Input
3. First Plate Affected
4. J^{th} Plate Not Affected

F-13

1. N_{11} Varying
2. N_{22I} Input
3. First Plate Not AFfected
4. J^{th} Plate Affected

F-14

1. N_{11} Varying
2. N_{22I} Input
3. First Plate Not Affected
4. J^{th} Plate Not Affected

F-15

1. Biaxial Ratio
2. First Plate AFfected
3. J^{th} Plate Affected

F-16

1. Biaxial Ratio
2. First Plate Affected
3. J^{th} Plate Not Affected

F-17

1. Biaxial Ratio
2. First Plate Not Affected
3. J^{th} Plate Affected

10.2 Continued ...

Test	Characteristics
F-18	1. Biaxial Ratio
	2. First Plate Not Affected
	3. J^{th} Plate Not Affected
F-19	1. N_{22} Varying
	2. EPS 11 Input
	3. First Plate Affected
	4. J^{th} Plate Affected
F-20	1. N_{22} Varying
	2. EPS 11 Input
	3. First Plate Not Affected
	4. J^{th} Plate Affected
F-21	1. Mix of Curved and Flat Plates
F-22	1. Offsets on Plates
	2. Substructure Interrelationship Element Pairs
	3. Plates with Different A, B & D Matrices
F-23	1. Rectangular Beam with 2 Layers
	2. Angle of Beam is Non-Trivial
F-24	1. Rectangular Beam with 1 Lamina
F-25	1. General Beam Element
F-26	1. Circular Beam with 3 Laminas

10.2 Continued ...

Test	Characteristics
F-27	1. Plate with 3 Layers 2. Rectangular Beam with 15 Layers 3. Similar Plates with Different Boundary Conditions 4. Similar Plates with Same Boundary Conditions with Different Widths 5. Non-Neglected Plate Element with Non-Interior Node
F-28	1. Flat Plate with Zero B-Matrix 2. N_{22} Varying 3. Non-Zero N_{11} Side Load Input
F-29	1. Flat Plate with Zero B-Matrix 2. N_{11} Varying
F-30	1. Curved Plate with Non-Zero B-Matrix 2. Non-Zero N_{11} Side Load Input 3. N_{22} Varying
F-31	1. Curved Plate with Non-Zero B-Matrix 2. Non-Zero N_{22} Side Load Input 3. N_{11} Varying
F-32	1. Determinant Always Positive 2. 0/2 Buckling Condition
F-33	1. Curved Elements with Zero B-Matrix and Different Radii 2. Similar Plates with Same Boundary Conditions with Same Widths 3. Similar Plates with Same Boundary Conditions with Same Widths and Same Spring Stiffness

10.2 Continued ...

Test	Characteristics
F-34	1. Curved Plate with Zero B-Matrix, N_{22} Varying .
F-35	1. Multiple Root Searching
F-36	1. N_{22} Varying, N_{11} Input Case with Some Unaffected Elements. MØPT = 3 Used and Buckling Only Option Used
F-37	1. Flat Plate with $B_{ij} \neq 0$ with Input Upper Bound and MØPT = 1. Q_{ij} of One Plate Input with P-2 Card, Q_{ij} of Another Plate Input with Table and Card. E, ν Input by Table, JPC(5) = 6; Default Subdivisions = 10; One Element Set = 5
F-38	1. Two Identical Plates with Different Spring Stiffnesses at the Same Sprung Sides Going Through the Upper Bound Calculations. Only Start and End Substructures are Used for This Problem.
F-39	1. One Beam is Circular with One Layer, the Other is a General Beam with Offsets. The Circular Beam is Input with Table. MØPT = 4 is Used.
F-40	1. Two Laminated Plates with Same Loads and Radii, But with Different Widths. These Plates are Not Considered Identical From the Stiffness Standpoint.
F-41	1. Too Many Nodes

10.2 Continued ...

Test	Characteristics
F-42	1. Too Many Elements
F-43	1. Too Many Beams
F-44	1. Too Many Plates
F-45	1. Bad Equivalent Node Data 2. Equivalent Nodes with Different Boundary Conditions
F-46	1. Bad Interrelationship Data
F-47	1. Too Many Values in M-List
F-48	1. No L Card
F-49	1. Non-Element Data Out of Order
F-50	1. Too Many Nodal Spring Stiffnesses
F-51	1. Too Many Plate Offsets
F-52	1. Too Many Interrelationship Element Pairs
F-53	1. Too Many Equivalent Node Pairs
F-54	1. Bad Table Input
F-55	1. Incorrect Number of Nodes Input
F-56	1. Bad Thickness Table
F-57	1. Too Many P Cards
F-58	1. Too Many B Cards Input
F-59	1. Invalid Load Option

10.2 Continued ...

Test	Characteristics
F-60	1. Invalid Wave Number Search Option
F-61	1. Too Many N Cards
F-62	1. Illegal Boundary Condition
F-63	1. Wrong Number of Spring Stiffnesses Input
F-64	1. Bad User ID on Nodal Stiffness Set
F-65	1. Bad User ID in Interrelationship Data
F-66	1. Bad User ID in Equivalent Node Data
F-67	1. Bad User ID in Substructure Definition
F-68	1. Incorrect Number of Substructure Definition Node Pairs Input
F-69	1. Substructure Definition Element Pair Out of Order
F-70	1. Interrelationship Between Substructures Invalid
F-71	1. Invalid Node Used on Plate
F-72	1. Invalid Node on Beam Definition
F-73	1. Incorrect Number of Plates Input
F-74	1. Incorrect Number of Beams Input
F-75	1. Node in Start Substructure with Attachment to Element to Repeat, But Not Part of a Connection Node Pair.

10.2 Continued ...

Test	Characteristics
F-76	1. Substructures with No Interior Node
F-77	1. Panel with 2 Substructure, But No End Substructure
F-78	1. Boundary Condition on Beam Node
F-79	1. Beam Node Which is Not Equivalenced
F-80	1. Element with Nodes in Start and End Substructure
F-81	1. IPC(1) = 1
F-82	1. IPC(2) = 1
F-83	1. IPC(3) = 1
F-84	1. IPC(4) = 1
F-85	1. IPC(5) = 1
F-86	1. IPC(6) = 1
F-87	1. IPC(7) = 1
F-88	1. IPC(8) = 1
F-89	1. JPC(4) = $n < 100$ and $n \neq 0$
F-90	1. Duplicate User ID on Nodes 2. Duplicate User ID on Beams 3. Duplicate User ID on Plates

Thermal Stress Problems

Test	Characteristics
S-1	1. Four flat plates 2. Two general beams 3. Simply supported node 4. Plate with left node constrained 5. Plate with right node constrained 6. Plate with no node constrained 7. Repeated element types 8. Start substructure only
S-2	1. Two curved plate plate with non-zero B matrices 2. Repeated element types 3. Sprung node
S-3	See Section S-6
S-4	1. Beam in repeat substructure 2. Plate in repeat substructure
S-5	1. Plate offsets 2. Beam at angle 3. Start, Repeat and End substructures
S-6	1. Start and End substructures 2. Curved plates with zero B-matrix 3. Repeated element types 4. Sprung node
S-7	1. T_z input 2. Flat plate with non-zero B-matrix

Test	Characteristics
S-8	NUMX < 0
S-9	No thermal input on beam
S-10	Thermal Data on General Beam
S-11	1. Thermal Data on Rectangular Beam 2. Thermal Data on Circular Beam

Test	Characteristics
B-1	1. LOADOP = 5
	2. Two subelements per elements
B-2	LOADOP = 6
B-3	1. LOADOP = 7
	2. Start Substructure only
B-4	LOADOP = 8
B-5	Upper bound for LOADOP = 7
	$N_{11} \neq 0$, $N_{22} \neq 0$ and
B-6	Subelement N_{11} > Galerkin upper bound
B-7	Subelement N_{11} > Reduced subelement upper bound
B-8	N_{11} = 1000 constant
	Upper bound for LOADOP = 8
B-9	All $N_{11} \neq 0$ and $N_{22} \neq 0$
B-10	$N_{11} = 0$ on one subelement, rest $\neq 0$
	$N_{22} = 0$ on same subelement, rest $\neq 0$
B-11	$N_{11} = 0$ on one subelement, rest $\neq 0$
	$N_{22} = 0$ on same subelement, rest $\neq 0$

Test		Characteristics
B-12		$N_{11} \neq 0$ on one subelement, rest $\neq 0$ $N_{22} = 0$ on same subelement, rest $\neq 0$
B-13		Subelement N_{11} > Galerkin upper bound $N_{22} = 0$ for same subelement
B-14		Subelement N_{11} > Galerkin upper bound } same Subelement N_{22} > Galerkin upper bound } subelement
B-15		Subelement N_{22} > Galerkin upper bound $N_{11} = 0$ for same subelement
B-16		$N_{11} = 0$ and $N_{22} = 0$ for one element
B-17		$N_{11} = 0$ and $N_{22} = 0$ for all elements
B-18		Subelement N_{11} > reduced subelement upper bound $N_{22} = 0$ for same subelement
B-19		Subelement N_{11} > reduced subelement upper bound Subelement N_{22} > reduced subelement upper bound
B-20	same subelement {	Subelement N_{22} > reduced subelement upper bound $N_{11} = 0$ for same subelement
B-21		1. Beam Load 2. Start, Repeat and End substructures 3. Externally loaded

Test	Characteristic
B-22	1. Externally loaded
	2. Start and End substructure
B-23	1. IPC(9) = 1
	2. IPC(10) = 1
	3. IPC(11) = 1
	4. IPC(12) = 1
	5. IPC(13) = 1
	6. IPC(14) = 1
	7. Input default number of subelement
	8. No thermal input on one plate
B-24	No load on one plate element

REFERENCES

1. Viswanathan, A. V., Tamekuni, M.: Analysis for Stresses and Buckling of Heated Composite Stiffened Panels and Other Structures. NASA CR 112227, 1973.

2. Viswanathan, A. V., Tamekuni, M.: Elastic Buckling Analysis for Composite Stiffened Panels and Other Structures Subjected to Biaxial Inplane Loads. NASA CR 2216, 1973.

3. Bushnell, D., Smith, S.: Stress and Buckling of Nonuniformly Heated Cylindrical and Conical Shells, AIAA Journal, Vol. 9, No. 12, December 1971, pp. 2314-2321.

4. Gagnon, Claude R.: Generalized Eigenproblem for Large Matrices with a Repeated Block Structure. Internal Report MA-189, Numerical Analysis Staff, Boeing Computer Services, Seattle, Wash., July, 1970.

5. Lu, Paul: Equation Solver and Generalized Eigenproblem for Large Symmetric Matrices with a Special Block Structure. Internal Report MA-237, Numerical Analysis Staff, Boeing Computer Services, Seattle, Wash., April, 1971.

APPENDIX

During the running of the thermal buckling problem shown in Section 8.3, singularities were encountered in the program in the subelement processing stage. By re-modelling the cylinder, a successful solution was achieved.

The original idealization consisted of three equal wide elements between nodes 8 and 21 of Figure 8.3. The re-modelled cylinder shown in Figure 8.3, has thirteen elements (8 to 20) instead of the original three elements. This change in idealization which reduces the element width, 'bypassed' the singularity problems.